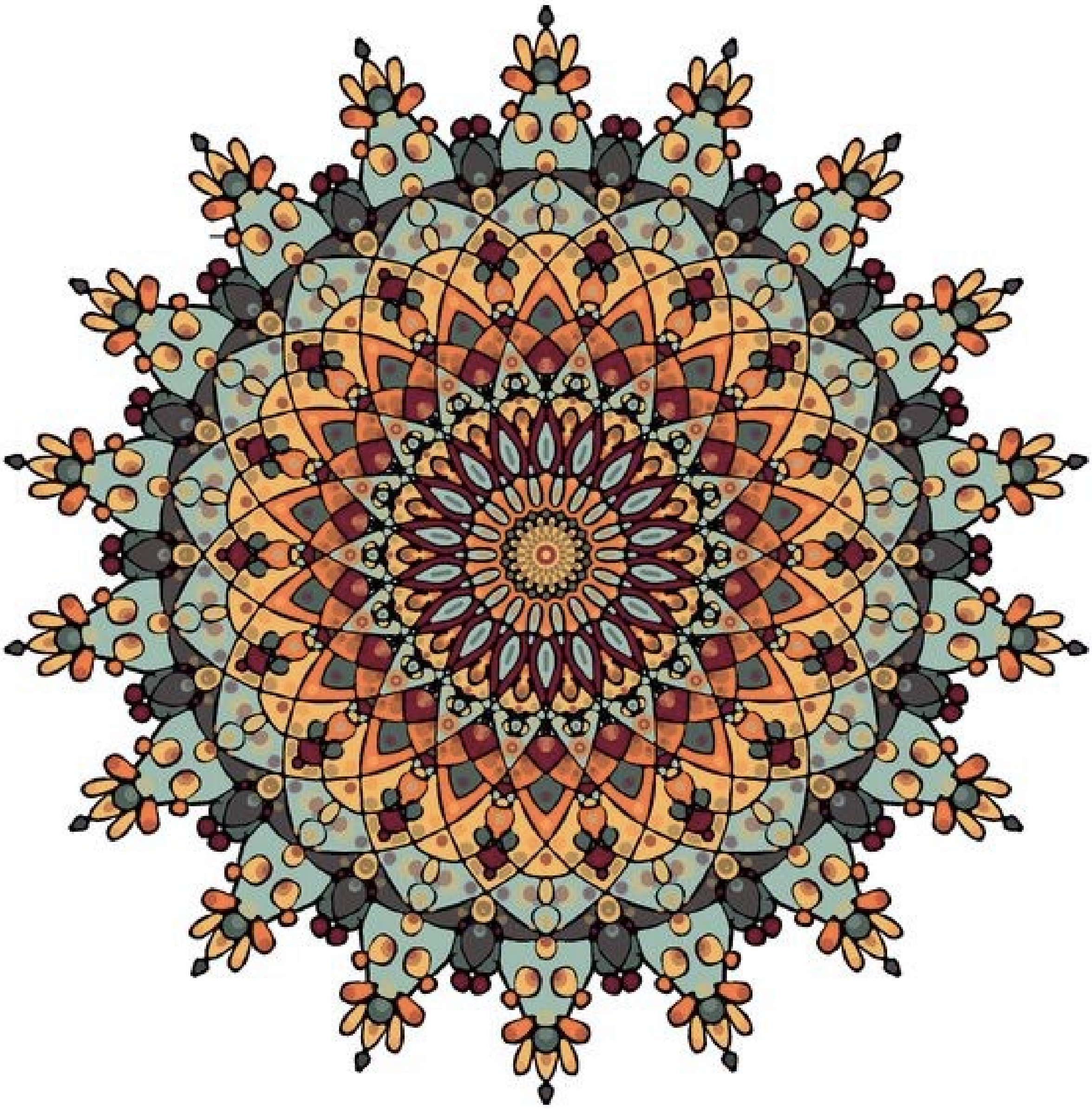
Research-practice gaps in circularity indicators for the plastic industry in the Netherlands



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Abstract

Research-practice gaps in circularity indicators in the plastic industry in the Netherlands were identified. The Dutch government aims for a complete circular economy in 2050. A circular economy in the plastic industry is projected to decrease crude oil use, CO2 emissions, waste and litter (Stegmann et al., 2022; Robaina et al., 2020). Monitoring improves environmental performance (Zou, 2021), influences decision making and creates accountability for companies. Optimising CE indicators for the plastic industry, by identifying r-p gaps, contributes to better circularity performance. The implementation scale of the indicators, CE discourses and indicator typology were compared between the research and practice field with a structured literature review. Expert interviews provided explanations and context for the gaps. Identified research-practice gaps are: the complexity of wording and calculations of indicators from research; a larger focus on indicators for new business models, social change and the use-phase in the practice field; a larger focus on financial indicators in research. For both fields, standardisation of CE indicators and improved communication between the two fields would benefit CE monitoring. Future research should focus on bridging these gaps.

Key words

Research-practice gaps – circular economy – circularity indicators – plastic industry

Summary

The Dutch government and European Union have committed to a circular economy in 2050 (*A circular economy in the Netherlands by 2050, 2018; European Commission, 2018).* One of the key raw material chains that is undergoing this transition is the plastic industry, since a lot of crude oil is used as raw material here (*A circular economy in the Netherlands by 2050, 2018; Transition Agenda Circular Economy Plastics, 2018)*. As circularity monitoring systems are being developed, a multitude of circularity indicators have been proposed in academia and in practice (Saidani et al., 2019). Adding to the complexity, many interpretations of the CE concept exist (Calisto Friant et al., 2020). This research studies to what extend the research and practice fields connect to each other and what research-practice gaps exists.

This research answers the research question: '*What are research-practice gaps in circularity measurement in the plastic industry in the Netherlands?*'. With answering this question it aims to contribute to improving CE indicators in the plastic industry in order to increase its circularity performance. The research zooms in on three elements: the implementation level of the indicators in both fields; the CE discourse present in the selected research and practice documents; and what the indicators measure using indicator categories.

The methods used are structured literature review complemented by semi-structured expert interviews. With the literature review, indicators are extracted from research and practice documents. The indicators are evaluated with the three elements mentioned above. The expert interviews provide insights and explanations for the differences observed from the analysis of the literature review.

The results and conclusions are summarised in the table below.

	Addressed in Research	**Not addressed in research**
Addressed in practice	<u>Obstacles in research and practice</u> - no uniform definition and complexity of the term CE - limited communication streams between research and practice	<u>Inspiration for research</u> - include more practice (case studies, interviews, communication) and understand their practical situation - indicators for new business models on micro level - use-phase indicators on micro level - use simple wording and calculations
Not addressed in practice	<u>Inspiration for practice</u> - make more data available - develop or use more financial indicators	<u>Opportunities for both fields</u> - standardisation of CE indicators (ISO is being developed).

From the results it is concluded that research-practice gaps exist. The research field is lacking in the amount of practice incorporated in research; indicators for new business models and use-phase on micro-level; the use of comprehensible wording and calculations for practice. The practice field is lacking in the use of financial indicators and the data that practice actors make available. Future research should focus on how to overcome these gaps.

Preface

Here it is, my final project of the master study. This remarks a memorable time in my life. With the completion of this master's thesis, my time as a student has ended and a new phase of adulthood begins.

Above all my expectation, I genuinely enjoyed working on this thesis. Of course, there were difficult moments, but seeing that I can work through them without abnormal amounts of cortisol in my body, made me realise how much I have learned during my study. I am glad I found the topic to be interesting throughout the project and even see myself working with circularity or monitoring in the future.

I would like to thank my supervisor, Sietske Veenman, for her time, trust and tips, and even for some of the difficult moments. Thanks to Kymé and the other students, who repeatedly reminded me that we were not alone in this thesis process. And thanks to my support at home, especially Luuk for balancing the cortisol with a lot of endorphins and oxytocins.

Although, my internship was separate form my thesis topic, it contributed to my skills for completing this thesis. Therefore, I would like to thank Sarah and Sarah for giving me the opportunity to do an internship at the Ministry of Infrastructure and Water management, and Jos Benner for his guidance, positive feedback and confidence in my abilities.

For anyone who reads this, thank you for your interest and possibly your participation and information. I hope that something in this thesis will bring you new insights or provides interesting information, so that the efforts in this thesis project exceeds the sole purpose of graduating.

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Glossary

CE	Circular Economy
E&P	Extraction and Production
EoL	End-of-Life
EU	European Union
PBL	'Planbureau voor de Leefomgeving', Netherlands Environmental Assessment Agency
ICER 2021	Integral Circular Economy Report 2021
SMEs	Small and Medium Enterprises
Indicator	One measurement element of the monitoring framework, *metric* is used interchangeably. The set of indicators from one document forms a monitoring framework.
Instrument	Interchangeably used with *tool*. A bundle of indicators, or accumulation to a single indicator, proposed or offered by one organisation.
LCA	Life Cycle Analysis
MFA	Material Flow Analysis
indicator framework	A set of indicators proposed by one article or report
RE	Resource Efficiency
r-p gaps	Research-practice gaps

1 Introduction

In this introduction, first the problem statement is described. Then, the research aim and question are formulated. This is followed by the scientific and societal relevance of the research. Lastly, a reading guide for the document is included.

1.1 Research problem statement

The Dutch government and European Union are committed to a circular economy in 2050 (*A circular economy in the Netherlands by 2050,* 2018; European Commission, 2018; Calisto Friant et al., 2022). The plastic industry has agreed to accelerate the transition towards a circular economy (*Grondstoffenakkoord*, 2017). Along with many other countries, the Netherlands has a 'Plastic Pact', in which the government and more than one hundred companies in the industry commit to goals that aim to improve the circularity of the plastic industry. In academia, the term circular economy is also gaining popularity, each year more articles are published containing the term (Reike et al., 2018).

The plastic industry accounted for 4,5% of global greenhouse gasses in 2015 (Cabernard, 2022) and continues to grow its production (Oktavilia et al., 2020). With no transition, the plastic demand is projected to double by 2050, accompanied with an almost similar increase in CO2 emissions (Stegmann et al., 2022). A circular economy approach is projected to reduce primary resources of the plastic industry with 30% and reduce CO2 emissions in a range from 10% to even a negative balance in 2050, depending on the strategy (Stegmann et al., 2022). Additionally, a circular economy in the plastic industry reduces waste and litter (Robaina et al., 2020).

To accomplish this and to guide political decisions, CE monitoring is being developed. Monitoring and regulatory enforcement are still the number one motivators for companies to comply to environmental performance (Wayne and Shimshack, 2011). Environmental performance is found to be better on monitored days (Zou, 2021). Companies start voluntarily monitoring their performance to show their level of circularity, like the ISO 14001 standard for environmental management or the various circularity measuring tools offered for companies (Nederland Circular!, 2021). However, to this date there is no standardized, broadly accepted CE monitoring framework in place.

The connection between research and practice of CE indicators is important in order to develop well-functioning indicators. Research can provide academically tested monitoring methods and objective evaluation of indicators. However, the circular economy concept was mainly developed by the practice field, i.e. policy-makers and the business field (Korhonen et al., 2018). Although the amount of scientific articles published about CE has increased in the last decade (Elia et al., 2017), it is believed that the scientific research field of CE is largely unexplored (Korhonen et al., 2018). Identifying research-practice gaps in CE indicators helps to connect the research field to the practice of CE and the practice field to gain knowledge from the research field. This contributes to the development of CE indicators for the plastic industry that play an important role in the transition to a CE.

The academic debate on what to monitor for progress on the CE is on-going and a variety of indicators is used and proposed (Sainidi et al., 2019; Rincón-Moreno, 2021). While in practice, companies already use monitoring tools to communicate their circularity performance developed by various organisations and consultancies (Nederland Circulair!, 2021). Policy reports address what to monitor in the transition towards a circular economy on macro scale. Prominent reports are among others the 'Integrale Circulaire Economy Rapportage' (PBL, 2021), the Circular Economy Indicators from Eurostat (n.d.) and the monitoring from PlasticPactNL (2020).

This research studies research-practice gaps in circularity indicators for the plastic industry. By doing so, it identifies opportunities for the research field to establish a better connection with the practice field and perform relevant research. And it identifies opportunities for the practice field to learn from the academically tested indicators. With the results, circularity indicators can be optimised and monitoring of circularity progress can be improved. Accurate monitoring will positively effect environmental performance (Zou, 2021), and thus improve circularity in the plastic industry.

Research-practice gaps will be identified, using a theoretical framework that contains different dimensions. The implementation scale of the indicators, the typology, and the CE discourse are compared between the research and practice field with a literature review. Expert interviews provide a deeper understanding of the differences found in the literature review.

1.2 Research aim and question

The aim of this research is to identify research-practice (r-p) gaps in circularity indicators for the plastic industry in the Netherlands, in order to increase the circularity of the plastic industry. This reduces crude oil use, CO2 emissions and plastic litter. With identifying r-p gaps, firstly, the research done on circularity indicators will be more relevant for circularity monitoring in practice. And secondly, the practice of monitoring will contribute to better research on circularity indicators. Well-functioning and clear indicators improve decision-making and create accountability for actors in the plastic industry, which all improve the circularity of the plastic industry.

The following research question and sub questions guide the research:

What are research-practice gaps in circularity measurement in the plastic industry in the Netherlands?

1) At what scale do the two fields measure circularity?

2) From which CE discourse do the indicator frameworks approach CE?

3) What do the indicators measure in both fields and what are explanations for the differences?

1.3 Scientific and societal relevance

The relevance of this research is discussed and what added value it has to the science and to society.

1.3.1 Scientific relevance

Although there is no research on research-practice gaps in indicators for a circular economy, there are some articles with closely relating topics. Monitoring of the CE is a research field of the last decade (Elia et al., 2017). Evaluative literature on CE monitoring does exist (Jerome, 2022; Elia et al., 2017; Rincón-Moreno et al., 2021), however these mainly focus on indicators from literature. The following paragraphs describe related articles and it is discussed how this research differs from those studies and supplements the available knowledge.

In literature, the importance of indicators is discussed (Brocken et al., 2017; Rincón-Moreno et al., 2021; Superti et al., 2021). Indicators are important: to understand if circularity is occurring and whether it is beneficial (Brocken et al., 2017); as support for decision-making; for communicating data (Superti et al., 2021); and to simplify complexity (Morse, 2015). This stresses the importance of clear CE indicators. The CE in the plastic industry improves when it is monitored, as it leads to better informed decision-making and simplifies the complexity around the concept. Identifying r-p gaps between the two fields contributes to improving CE indicators and CE performance of the plastic industry.

Keirstead and Leach (2008) describe research-practice gaps in urban sustainable development indicators. They found that the indicators they studied often lack a clear explanation of sustainability principles, which creates uncertainty about the goals it tries to contribute to. Since sustainable development and circular economy both are concepts of a similar complexity and abstraction level, a comparable situation could exist for CE indicators. This means it is important to have a clear understanding of the circular economy principle. This is not always the case, many different interpretations and definitions exist (Calisto Friant et al., 2020; Kirchherr et al., 2017). With identifying r-p gaps, this research looks at different interpretations of CE between the research and practice field based on the indicators. Being aware of these differences contributes to improve CE indicators.

Research-practice gaps were studied for blockchain for the circular economy (Böckel et al., 2021) and for circular supply chain management (Zhang et al., 2021). The structure and methods of these articles are very insightful for this research. The articles have several overlapping concepts and a similar aim as this research. This research distinguishes itself with its focus area: it focuses on CE indicators for the plastic industry. Thus, adding to literature of r-p gaps in the circular economy in order to increase circularity performance of the plastic industry.

Circular economy indicators have been analysed by Saidani et al. (2019) with a literature review using a ten category framework. One of the categories is the background and origin of the indicators, making a distinction between academics, organisations and companies. Indicators developed in all these three area's were included in the study. However, differences between these fields were not discussed in the results. The indicators were compared on different elements with the aim to provide a circularity indicator taxonomy (Sainidi et al., 2019). Based on the taxonomy they created the 'C-Indicators Advisor', they explained: *'The goal of this selection tool is to support the users in identifying and selecting the most appropriate circularity indicators in line with their requirements. It is mainly intended to industrial practitioners, decision-makers and policy-makers working in CE projects.'* (Saidani et al., 2019, p 551). This tool is in itself an attempt to bridge the research-practise gap, in making the knowledge of existing indicators more accessible for the practice field. However, a grounded discussion of actual research-practice gaps and barriers is missing. This research adds to this study by zooming in on their category 'background and origin of the indicator' with a particular focus on the plastic industry and tries to identify gaps between the research and practice field. Future research suggested by Saidani et al. (2019) should *'evaluate and judge more objectively the definition, relevance and scientific soundness of C-indicators, so that one can have more trust and confidence in their use.'* (p. 556). This recommendation is integrated in the aim of this paper. By studying research-practice gaps the relevance of circularity indicators for practice actors will be discussed. The issue of trust is integrated in the aim of this paper to optimise CE indicators for the plastic industry in order to increase its circularity.

The diversity of definitions and interpretation given to circular economy is pointed out by many authors (Saidani et al., 2019; Virtanen et al., 2019; Kirchherr et al., 2017; Korhonen et al., 2018). This is a problem, because it creates fussiness around the concept and actors interpret it in different ways. This compromises the validity of circularity indicators, since these also are interpreted in different ways. This research does not aim to clarify the terminology of CE, but to contribute to the understanding of differences in the research and practice field of CE indicators in the plastic industry. Once we understand and know differences between the research and practice field, we can start working to bridge the gap and optimise CE indicators in order to increase the circularity in the plastic industry.

This research differs from previous studies because it studies a new, undefined field. Is looks at research-practice gaps in CE indicators for the plastic industry. It builds on previous research on research-practice gaps and circularity indicators. However, the combination of these two fields has not been studied. The knowledge this study will provide, contributes to the understanding of r-p gaps and to the development circularity indicators in both academia and in practice. With this knowledge, CE indicators can be optimised which increases the circularity of the plastic industry by influencing decision-making and accountability of companies.

1.3.2 Societal relevance

The societal relevance of this research is first an foremost, that it contributes to the transition towards a circular economy for the plastic industry. This reduces CO2 emissions and plastic waste (Stegmann et al., 2022; Robaina et al., 2020). Plastic pollution harms the ecosystem in various ways and has possibly even a toxic effect on human health (Li et al., 2021). By identifying research-practice gaps in CE indicators in the plastic industry, this research contributes to the transition towards a circular plastic industry.

A more direct societal effect of identifying r-p gaps of CE indicators, is this information contributes to optimising CE indicators. With well-functioning indicators, policy makers can make better informed decisions and companies can communicate their performance better (Jerome et al., 2022; Superti et al., 2021) and be held accountable by pressure from societal actors. Consumers benefit from this, as they can make better informed decisions.

This research is also relevant for companies in the plastic industry. It contributes to connecting the practicality of CE monitoring these actors experience to the scholarly debate, so that the development of CE indicators can be optimised. Indicators developed which account for the practicality of monitoring, are better suited to be used by companies and to monitor their circularity. This also means it becomes easier to know how to improve their circularity performance.

1.4 Reading guide

This document consists of the following: first, the literature review describes existing literature on key concepts. Second, the theoretical framework explains the interaction of relevant concept for answering the research question. Third, the methodology is explained, including the research strategy and methods, operationalization and analysis. Fourth, the results from the structured literature review and expert interviews are discussed. Then a discussion and reflection are included, followed by the conclusion and future research recommendations.

2 Literature review

In order to answer the research question, it is important to understand the key concepts and to know the state-of-the art literature on the topic. The key concepts to identify research-practice gaps in CE indicators for the plastic industry are research-practice gaps, circular economy, CE discourses and monitoring of CE. State-of-the-art literature on these topics is discussed respectively to understand these topics.

2.1 Research-practice gaps

Research-practice gaps have been identified in a range of fields, like education, psychology, linguistics and medicine and are described in literature for decades (Bourque, 1969; Böckel et al, 2021). Different understandings of the research-practice gap, also termed as theory-practice gaps, exist in literature. Böckel et al. (2021) made a collection of different understandings they found in papers. From these understandings listed, two main themes are formulated: (1) a lack of research relevance and/or connection between research and actual practice, and (2) a knowledge transfer problem or communication gap, either a lack of searching by practitioners or lack of diffusion of research into practice. Two remaining understandings of research-practice gaps are a translation gap (especially in linguistics) or a time lag. However, these two interpretation are less relevant for CE indicators and outside the focus of this research.

Sitas et al. argued in 2014 that an established methodology to study research-practice gaps did not exist yet. However, since then, multiple studies used systematic literature review in which they compared research and practice literature to understand research-practice gaps (Böckel et al., 2021; Tkachenko et al., 2017; Jansen, 2018; Petit-Boix and Leipold, 2018).

Contributing factors of research-practice gaps described in literature are failures in communication, lack of public awareness, poor financing or non-supportive political atmosphere (Mallonee et al., 2006). Potential solutions to bridge research-practice gaps include experimenting with evidence from real customers (Shevchenko et al., 2023) and select niche indicators in a service-oriented framework instead of trying to measure *'overly ambitious visions of sustainable development all at once.'* (Keirstead and Leach, 2008, p.337).

In research-practice gap studies relating to circular economy, a recurring theme is the validity of the indicators (Keirstead and Leach, 2008; Zhang et al., 2021). Keirstead and Leach found in their research on research-practice gaps in urban sustainability indicators that *'the challenges of data acquisition often trump questions of analytical validity.'* (p.337). The practicalities of measurements and gathering the needed data, often influence the indicators used by actors. This can compromise the validity of the indicators, meaning in their case that the indicators might not represent sustainable development in its totality. For circular economy measurement, this means that actors in practice will choose easily usable indicators which do not necessarily cover the totality of the CE concept. It is important to include the practicalities of measurement in the scholarly debate on CE indicators, to overcome this mismatch. The research will identify if this research-practice gap is present for circularity indicators in the plastic industry.

Research-practice gaps in circular supply chain management have been identified by Zhang et al. (2021). One of the gaps identified was that research used mostly mathematical modelling studies in which the product context, a specific industry or real-life application was missing. This undermined the validity and relevance of the modelling results. Secondly, different meanings of circular supply chain were used. The literature mainly used closed-loop circular supply chain management, while in practice the open-loop circular supply chain management is considered realistic (Zhang et al., 2021). A third r-p gap in CE supply chain management was found in the different elements of sustainability: research mainly addresses economic and environmental performance in CE, where in practice social sustainability and resilience also play a role (Zhang et al., 2021).

To conclude, r-p gaps are understood as a lack of relevance of research for practice or as a knowledge transfer problem between the research and practice field. Gaps found in previous literature related to CE are amongst others: different meanings given to key concepts, problems with gathering of data, complex calculations in research and lack of application in practice, and non-supportive political atmosphere. To understand the concept of CE from an academic point of view, the next section discusses state-of-the-art literature on the circular economy.

2.2 The circular economy concept

The concept of the circular economy is widely discussed in literature. In this section, first, the development of the CE concept through time is discussed, followed by state-of-the-art definition form literature. Lastly, literature on strategies to transition towards a CE are discussed.

The circular economy is a well known term and gets increasing academic attention since the ’00 (Reike et al., 2018). The concept was created in the 1960 and developed into today’s concept of CE through the phases CE 1.0, CE 2.0 and CE 3.0 (Reike et al., 2018). The period from 1970-1990 is described as ‘CE 1.0’, in which the focus of waste management was on the output side. Governments took a regulating role and focussed on ‘polluter pays’ and ‘end-of-pipe’ solutions (Reike et al., 2018). In ‘CE 2.0’, the period between 1990-2010, the focus started to shift toward prevention, connecting input and output (Reike et al., 2018). Economic opportunities are seen in environmental problems in term efficiency gains and reputation gains (Blomsma and Brennan, 2017). The ‘CE 3.0’ is the phase from 2010 till now, in which resource depletion is linked to the humanity's survival. CE is embraced as a way to decouple growth from resource use (Reike et al., 2018).

The complexity and fuzziness of the term is often mentioned in literature. An analysis of 114 definitions by Kirchherr, Reike and Hekkert (2017), showed that CE means different things to different people. Their commonly used definition of CE reads:

> *'A circular economy describes as an economic system that is based on business models which replace the 'end-of-life' concept with reducing, alternatively reusing, recycling and recovering materials in production/distribution and consumption processes, thus operating at the micro level (products, companies, consumers), meso level (eco-industrial parks) and macro level (city, region, nation and beyond), with the aim to accomplish sustainable development, which implies creating environmental quality, economic prosperity and social equity, to the benefit of current and future generations.'* (Kircherr et al., 2017, p229)

This definition received the critique that it does not contain the properties of a good definition, namely only elements that are necessary or sufficient. It is too specific and at the same time too broad (Figge et al., 2023). The definition from Figge et al. (2023), based on the criteria for a good definition reads:

> *'The circular economy is a multi-level resource use system that stipulates the complete closure of all resource loops. Recycling and other means that optimise the scale and direction of resource flows, contribute to the circular economy as supporting practices and activities. In its conceptual perfect form, all resource loops will be fully closed. In its realistic imperfect form, some use of virgin resources is inevitable."*(Figge et al., 2023, p2)

This theses aims to identify differences between research and practice. For this reason, the fact that CE is defined differently by different people is more important than finding the most accurate definition. What is interesting from these definitions, is that Figge et al. (2023) recognises a difference between conceptual form and realistic form. Both definitions include the multi-level component of CE, this is elaborated on in the theoretical framework. In Figge's definition, the sustainable development component is not deemed essential for the concept of CE, where in Kircherr's definition this is included. Potting et al. (2017) noted that in practice this is also debated, for some companies this is an additional benefit, others see environmental improvements as integral part of CE.

Different strategies are used to move toward a circular economy. Amongst others: sustainable and eco-design, energy and material efficiency measures, strategies defined within an R- waste hierarchy (see Table 1), business model innovation or industrial symbiosis (Corona et al., 2019). It is mainly the industrial sector who caries out these strategies.

The Integral Circular Economy Report ICER 2021 (PBL, 2021), which reports the state of the circular economy is the Netherlands, also describes transition processes. Eight essential processes are identified for the success of the CE transition. This report focussed on macro scale from a policy perspective. For each process, indicators based on literature are identified. The eight processes are: (1) entrepreneurship (experimenting and scaling up of innovations); (2) knowledge development; (3) exchange of ideas; (4) giving direction by stating goals and solutions; (5) creating markets; (6) mobilising resources; (7) breaking resistance; (8) coordinating the complex bundle of transition processes.

The 'R-hierarchy' is one of the most commonly used theories to structure sustainability of material and product use. It categorises multiple value retention options from more to less sustainable. There are multiple 'R' hierarchies in literature, ranging from 3 to 10 R's. in the context of the CE, most articles use 3 R's (Reike et al., 2019). Reike, Vermeulen and Witjes (2018) did an extensive literature review and developed a 9R value-retention hierarchy, see Table 1. The highest rank (R0) is the most sustainable option, the lowest rank (R9) the least sustainable. R0-R3 are short loop activities, R4-R6 are medium long loop activities and R7-R9 are long loop activities (Reike et al., 2018). A version of the R-hierarchy is often used in monitoring of circularity. Other elements in CE monitoring are discussed in the following section.

Table 1. Value Retention Options (from Reike et al., 2018)

Rank	Retention option	Explanation
R0	refuse	Refuse the usage of the product and make product redundant
R1	reduce	Reduce the material per product or the consumption per time
R2	reuse/resell	Product works as new and is used by second consumer
R3	repair	Replace broken parts and bring back to as new state, extend its lifetime
R4	refurbish	Make products up-to-date, replace part with newer ones
R5	remanufacture	Disassembling, checking, cleaning and when necessary replacing or repairing of products in an industrial process
R6	re-purpose	Using (part of) discarded goods to make products with new function
R7	recycle materials	Processing mixed waste streams to recover materials for any purpose, and avoid mining of new materials
R8	recover energy	Capturing the energy from waste streams mostly form incineration
R9	re-mine	Retrieval of materials from landfills, operational or by 'scavengers'

2.3 Monitoring of CE

Monitoring and evaluation have been proven to be a success factor in project or policy success (Seasons, 2003; Gathege and Yusuf, 2019; Lopez-Acevedo et al., 2012). In the process of decision making, quantitative assessment frameworks are necessary to monitor changes and support the decisions (Jerome et al., 2022). The European Commission recognises that monitoring is key '*to understand how the various elements of the circular economy are developing over time, to help identify success factors in Member States and to assess whether sufficient action has been taken*' (European Commission, 2018, p 1). At the same time, evaluating and assessing the full impact of the CE is one of the main challenges the CE faces (Calisto Friant et al., 2020).

There are multiple types and ways of monitoring. A distinction can be made between single indicator monitoring, sometimes called aggregated scores, and multiple indicator monitoring tools (Corona et al., 2019; Elia et al., 2017; Jerome et al., 2022). For the CE, it is often found that single indicator tools offer only a limited assessment of the level of circularity (European Commission, 2018; Elia et al., 2017).

An second distinction that is made, is on the level the monitoring is implemented: on micro, meso and macro level (Elia et al., 2017; Kirchherr er al., 2017; Calisto Friant et al., 2020). Generally, micro level is a single company or consumer, meso level is e.g. an industrial park or industry and macro level is a city or nation. Distinctions in how these three levels are defined by different papers, and how they will be defined for this study, can be found in the Operationalization.

The common statement that little CE indicators and monitoring for CE are available, which Potting et al. (2017) also stated, was contested and proven wrong by Saidani et al. (2019). They analysed a large dataset of CE indicators using ten categories: level, loops, performance, perspective, usages, transversality, dimension, units, format and sources. They concluded that contrary to what many authors claim, there is a multitude of circular economy indicators available. At the same time, this multitude represents a richness of interpretation of what should be measures in CE, which causes fuzziness on the meaning of indicators. However, indicators are needed to monitor progress and provide direction (Saidani et al., 2019).

Monitoring frameworks with similar purposes to CE monitoring exists, without specifically being developed for CE (Elia et al., 2017). Existing indicators for sustainable development are often used in circularity assessment (Vadoudi et al., 2022; Elia et al., 2017). Examples are Carbon Footprint, Material Flow Analysis (MFA), Life Cycle Assessment (LCA). However, they are also critiqued to be fit for CE. The Carbon Footprint is a single indicator tool, it only account for greenhouse gas emissions expressed in CO2-equivalent. With the MFA framework, multiple indicators are included. It provides information about the quantity of materials used, it does not account for all environmental impacts. The quality of recycled material is not included, which is an important element of CE. The LCA framework includes multiple indicators. LCA is one of the most complete assessment methods. This means however, that large amount of data and time are needed to do the analysis, which increase the uncertainty of the analysis. Results are often only understood for expert audiences (Elia et al., 2017). With these different overlapping, but not completely fitting indicators, a good basis for CE indicator development already exists. The next section will explore different CE discourses and meanings given to circular economy.

2.4 CE discourses

To understand the concept of CE, different discourses are discussed in this section. Johansson and Hendriksson (2020) describe two discourses, a 'strong' and 'weak' interpretation of circularity. Calisto Friant et al. (2020) describe four CE discourses, which are places on a 2x2 along two axis (Figure 1).

In the CE discourse analysis of Johansson and Hendriksson (2020), two discourses are distinguished in Swedish policy documents: a weak interpretation of circularity and a strong interpretation of circularity. The weak interpretation looks at a circular economy, the strong interpretation looks more at eco-cycles. The first differentiation between the two is the focus on materials. In the eco-cycles discourse (the 'strong' interpretation), there is a focus on the start and end of the linear model, so both the extraction of materials and the cycling or reusing is seen as important for creating a circular system. In the circular economy discourse (the 'weak' interpretation), there is only a focus on the end of a linear system, on the recycling and reusing of materials. The extraction of materials from the earth is not seen as a problem, with the reserves expected to be large enough for the coming years (Johansson and Hendriksson, 2020). A second differentiation is that the eco-cycle discourse includes the view of smaller, more local cycles with the society involved in this reform. In the circular economy discourse the focus is on larger circular loops with still extraction of new materials and on the opportunity of new business models.

Calisto Friant et al., (2020) described discourses of the circular economy based on previous literature. They place four different discourses on two axis. First, on the horizontal axis, a distinction is made in the complexity with which CE is viewed, see Figure 1. The more simple view of CE only looks at material and energy resources in society and is mostly present at micro to meso scale, i.e. a product or region. CE is approached in a *segmented* way. This corresponds with the weak version of CE distinguished by Johansson and Hendrickson (2020). On the other side of the horizontal axis we find a more complex view of CE, which includes wealth, power, technology and knowledge in addition to material and resources. This looks at whole earth systems on macro-scale. It is CE from a more *holistic* approach. It encompasses more than just the economy, therefore Calisto Friant et al. (2020) call discourses on this side of the axis 'Circular Society'. This corresponds with the eco-cycle discourse Johansson and Hendriksson (2020) described.

Second, on the vertical axis, Calisto Friant et al. (2020) make a distinction between optimist and sceptical views of de role of technology and innovation in a sustainable society, see Figure 1. It relates to the debate on the necessity of degrowth. The *optimist* discourses does not see degrowth as necessary and believe that a solution can be found in technological innovation. It is optimistic about the current socio-economic system. The *sceptical* discourses is sceptical towards technological innovation and sees degrowth as necessary.

The holistic, optimist discourse is the *Reformist Circular Society*. There is a believe that the current economic and social system can be reformed to overcome scarcity of materials and energy. This includes technological innovation as well as behavioural change. In looks at all solution from the R-hierarchy, from reuse and repair to recycle, but has less focus on reduce. There is often a focus on the Sustainable Development Goals in this discourse or at the three dimensions of sustainability; environment, economy and social (Calisto Friant et al. 2020).

The holistic, sceptical discourse is named the *Transformational Circular Society*. A transformed system is envisioned in this discourse, in which economic downscaling and a better connection with the earth are seen as solutions for a sustainable society. Social and behavioural change towards more local, bottom-up and cooperative practises are central. Technological innovation is not seen as crucial, but it can play a role as long as it does not harm the ecosystem. There is an emphasis on changing the worldview to a more holistic and inclusive view, replacing the materialistic and individual one (Calisto Friant et al., 2020)..

The segmented, optimist discourse is the *Technocentric Circular Economy*. Increasing welfare is believed to coexist with decreasing human’s impact on ecology. There is a believe in the sustainability of capitalism. Developments in this discourse are e.g. carbon capture en storage (CCS), eco-design, recycle technologies. Calisto Friant, et al. (2020) describe this as the common discourse in European government policies, corporate strategies and business consultancies. This research will look at monitoring frameworks made by a.o. business consultancies and if the indicators they propose indeed corresponds with this discourse.

The segmented, sceptical discourse is the *Fortress Circular Economy*. This discourse stems from Malthusian theories and sees a solution in population control and material efficiency strategies. This view is found is the early stage of CE and is seen in times of geographical conflict or resource scarcity. Solutions are found in protecting geopolitical power, obtaining land in the Global South for securing resources, and holding back immigrants. This discourse is especially present in wealthy nations, who build a fortress in which their materials en energy is preserved (Calisto Friant et al., 2020).

		Approach to social, economic, environmental and political considerations	
		Holistic	**Segmented**
Technological innovation and ecological collapse	**Optimist**	**Reformist Circular Society** • *Assumptions:* reformed form of capitalism is compatible with sustainability and socio-technical innovations can enable eco-economic decoupling to prevent ecological collapse. • *Goal:* economic prosperity and human well-being within the biophysical boundaries of the earth. • *Means:* technological breakthroughs, social innovations and new business models that improve ecological health, resource security, and material prosperity for all.	**Techncentric Circular Economy** • *Assumptions:* capitalism is compatible with sustainability and technological innovation can enable eco-economic decoupling to prevent ecological collapse. • *Goal:* sustainable human progress and prosperity without negative environmental externalities. • *Means:* economic innovations, new business models and unprecedented breakthroughs in CE technologies for the closing of resource loops with optimum economic value creation.
	Sceptical	**Transformational Circular Society** • *Assumptions:* capitalism is incompatible with sustainability and socio-technical innovation cannot bring absolute eco-economic decoupling to prevent ecological collapse. • *Goal:* a world of conviviality and frugal abundance for all, while fairly distributing the biophysical resources of the earth. • *Means:* complete reconfiguration of the current socio-political system and a shift away from productivist and anthropocentric worldviews to drastically reduce humanity's ecological footprint and ensure that everyone can live meaningfully, and in harmony with the earth.	**Fortress Circular Economy** • *Assumptions:* there is no alternative to capitalism and socio-technical innovation cannot bring absolute eco-economic decoupling to prevent ecological collapse. • *Goal:* maintain geostrategic resource security and earth system stability in global conditions where widespread resource scarcity and human overpopulation cannot provide for all. • *Means:* innovative technologies and business models combined with rationalized resource use, imposed frugality and strict migration and population controls.

Figure 1. CE discourse typology (from Calisto Friant, et al., 2020)

The CE discourse in plastic policy in the Netherlands have been studies by Calisto Friant et al. (2022). Policy documents on circular plastic industry in the Netherlands are found to be mainly in the Technocentric Circular Economy perspective (Calisto Friant et al., 2022). Also in EU policy, techno-optimist views of CE are found to be predominant (Pinyol Alberich, 2023). This means there is a focus on technological innovations. However, it is highly unlikely that recycling alone will effectively reduce environmental impact, since plastic recycling technologies know many limitation. Higher R-strategies are recommended by Calisto Friant et al. (2022).

This two by two discourse framework is incorporated in the theoretical framework of this research. The next section elaborates on how this discourse framework is combined with two other frameworks form literature to identify research-practice gaps in the plastic industry in order to optimise CE indicators.

3 Theoretical framework

A theoretical framework is developed using multiple frameworks from excising literature. First, the three frameworks from previous literature are discussed. They are suitable to answer the research question, since they contain three widely discussed elements of the circular economy. Secondly, it is explained how these frameworks are combined to form the theoretical framework for this research.

The first key CE framework is the Circular Economy Framework (see Figure 2) of Elia et al. (2017). It describes Requirements to be measured, Processes to Monitor, Actions involved and Implementation levels. This framework is included in the theoretical framework, because it gives a clear overview of a CE system and includes the different implementation scales on which monitoring can be implemented. This element is used to answer the first sub question: *At what scale do the two fields measure circularity?*.

The three Implementation levels, macro, meso and micro, are a commonly used differentiation in CE literature and is defined in different ways (Kirchherr et al.; 2017 Calisto Friant et al., 2020; Corona et al., 2019). In this framework, macro level is defines as cities, regions and nations. Meso level is defined as industrial parks, and micro level is defined as companies or products (Elia et al., 2017). This distinction is importance, since the nature of the indicators is different for each level and often the indicator is not usable in another level. In the Operationalization in section 4.2, the precise definition used for this research is discussed.

The Processes to monitor are: material input, design, production, consumption and End-of-Life (EoL) phase. These correspond with the third key framework used in the theoretical framework of this research and is discussed below.

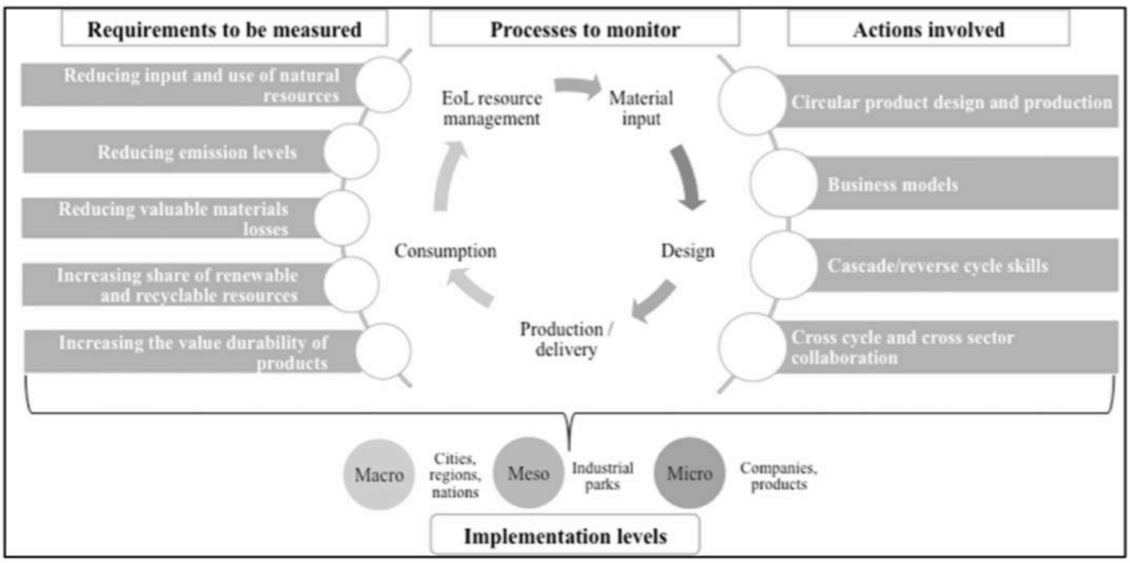


Figure 2. Ciruclar Economy Framework (from Elia et al., 2017)

The second key CE framework which this research builds on, is the 2x2 discourse framework of Calisto Friant et al. (2020). This was discussed in detail in section 2.4 and shown in Figure 1. This framework is included to answer the second sub question: *From which CE discourse do the indicator-frameworks approach CE?.* It identifies differences in how CE is approached in research and practice. Different understandings of the CE concept in the research and practice field, can result in different indicators to monitor CE. This framework helps to identify r-p gaps the different meanings that are given to CE and the indicators that follow from this.

The third key CE framework for this research is that from Böckin et al. (2020). They distinguish four typologies in CE measurements in three phases. In their article, they use the term resource efficiency (RE) instead of CE to not eliminate measures not specifically aimed at CE, but with the same function. The article focuses on the physical element of resource efficiency measured on product level. The four typologies are: Measures in Extraction and Production (E&P); Measures to Use Effectively and Efficiently; Measures to Extend Use; Post Use Measures (see Figure 3). This is similar to the five phases described by Elia et al. (2017): material input, design and production correspond with the E&P phase; consumption corresponds with the two use phases; and end-of-life corresponds with the post use phase.

In Figure 3 the four typologies are depicted. The E&P phase in yellow, the Use Phase in blue and the Post Use phase in green. This framework is used to answer the third sub question: *What do the indicators measure in both fields and what are explanations for the differences?*. This framework helps to answer the research question by identifying differences in what the indicators measure and for which phases indicators are developed. It categorises the indicators per phase and gives an overview of possible r-p gaps.

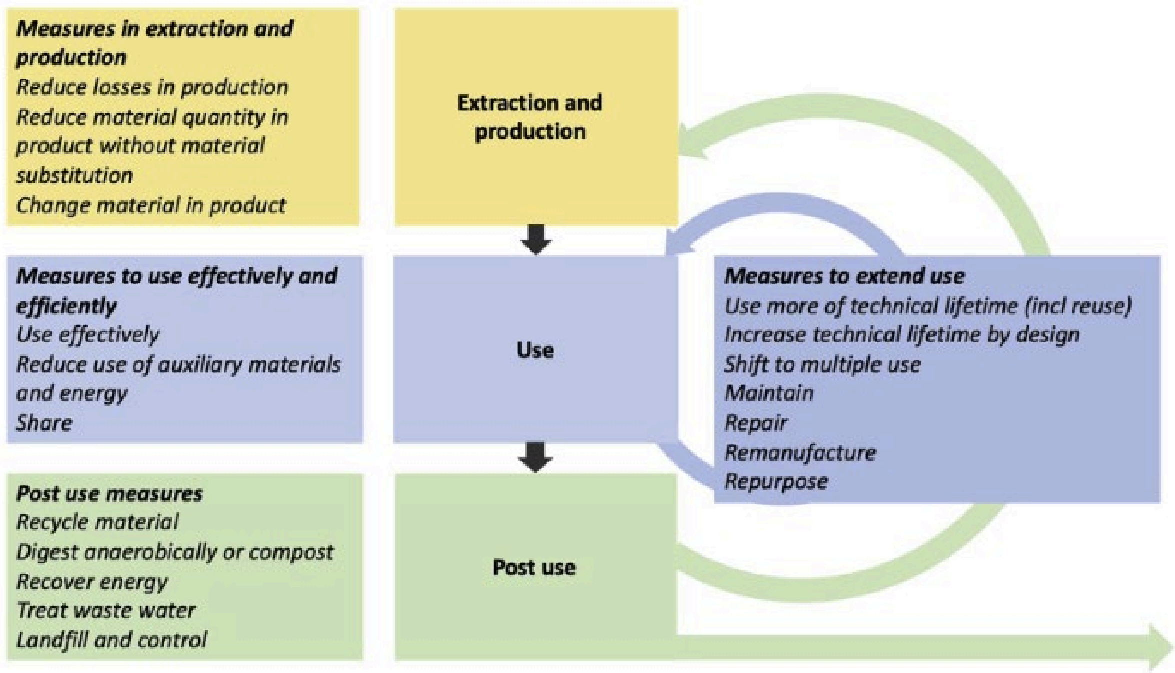


Figure 3. Resource efficiency typologies (from Böckin et al., 2020)

Each typology contains certain indicators, in which different R-strategies are integrated (see Table 1 on page 17). In Figure 3 the typologies form Bönkin et al. (2020) are depicted with examples of indicators per typology. These are also included in the reference indicators for this paper and are further discusses in Operationalization in section 4.2.

The CE framework from Elia et al. (2017), the CE discourses from Calisto Friant et al. (2020) and the measurement typologies from Böckin et al. (2020) are combined to form the theoretical framework for this research and is depicted in Figure 4. This framework is helpful in answering the research question because it includes commonly discussed elements from the circular economy and can provide a structured comparison between the research and practice field. The scales on which the indicators operate are included in the implementation level, the underlying values and meanings given to the CE concept are included with the discourses and the practical measurement properties of the indicators are included in the measurement typologies.

The purple circles at the bottom of Figure 4 indicate the implementation level of the framework and answers the first sub question of this research. Similarly as in the CE framework from Elia et al. (2017), the level can vary per set of indicators. They are depicted at the bottom of the framework underneath the bracket that indicates that the whole set of indicators proposed by a document is implemented on one of the levels.

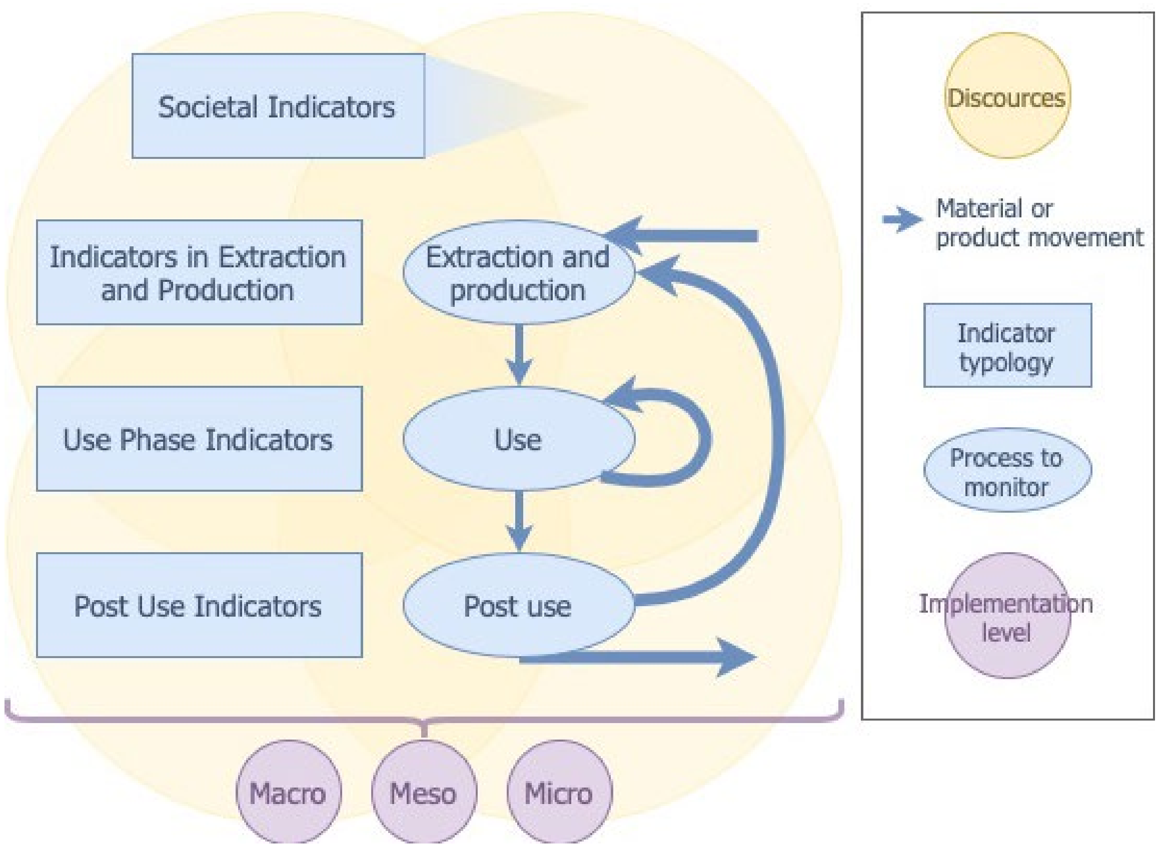


Figure 4. Theoretical framework

The yellow circles represent the four discourses described by Calisto Friant et al. (2020) and concerns the second sub question. They are placed in the background because they are a set of underlying views predominant in an environment. They are subconsciously present in all actions and ideas in this environment and form the course of action.

The blue section represent the measurement typologies and material flow from Böckin et al.'s framework (2020) and the Process to monitor from Elia et al., 2017. This guides the answer to the third sub question. The Societal Indicators are added based on the discourses from Calisto Friant et al. (2020), where a distinction is made between circular economy and circular society. These include measures on amongst other things new business models, socio-cultural change, equality, knowledge creation or monetary indicators. The interaction with the discourses is depicted with the colour gradient triangle. Changes in societal indicators can lead to changes in discourse, or a shift in discourse can lead to changes in societal indicators. The blue arrows represent the material or product movement, similarly as shown in the framework from Böckin et al (2020).

The indicator typology, in blue in Figure 4, is placed in the middle of the theoretical framework. This element looks at what the indicators measure and provides the most detailed information to what differences and disconnect exist between indicators from research and practice. The differences identified in the implementation level (purple) and in the discourses (yellow) give a more abstract indication of where possible gaps exist. These two elements are determined based on the indicator framework form one document as a whole. With the in-depth analysis of the indicators and what they actually measure, the more practical r-p gaps will be identified. This contributes to the aim of this research: to optimise CE indicators for the plastic industry in order to increase its circularity.

This theoretical framework gives an overview of widely discussed elements of CE, on which indicator frameworks might differ and how the elements are positioned in relation to each other. For each indicator framework included in the analysis is labelled with an implementation level and a discourse, after which each indicator is labelled with a typology. Subsequently, the differences between the research and practice fields are analysed.

4 Methodology

4.1 Research strategy and methods

This section explains the research strategy and lays out the research philosophy of the author. Since the philosophy largely influences the strategy, they are discussed subsequently.

4.1.1 Strategy and methods

The research strategy of this paper consists of two parts: 1) a document analysis, which analyses articles and tools and quantifies elements of CE indicators with frequency tables. And 2) expert interviews, in which experts in CE indicator development are interviewed for a better understanding of the research-practice gaps. This section first explains this choice for mixed methods and then goes into the quantitative and qualitative parts of the research.

This research was developed in a deductive theory frame, meaning the research aim and objective is formed based on theory (Bryman, 2012). The theory on different CE discourses, research-practice gaps and circular plastics formed the research aim to study research-practise gaps in CE indicators for the plastic industry. The research strategy is designed to investigate the differences and gaps between research and practice. The last step of deductive research often involves an inductive step, where the observations and findings form a theory (Bryman, 2012). This is done in the conclusion, when the results are interpreted and the research question is answered.

Mixed methods

Mixed methods was found to be most appropriate for this study, because the identification of research-practice gaps requires qualitative analysis in addition to quantitative analysis from the structured literature review. The quantitative data from the document analysis and qualitative data form the interviews complement each to get a full understanding of reality. Bryman (2012), and many other writers with him, points out that qualitative and quantitative research can both exist in the same research with mixed methods. Although the method is also critiqued (Bryman, 2012), it is increasingly used in social sciences and has been found to be a legitimate method (Archibald et al., 2020). Mixed methods give context and meaning to numerical data (Archibald et al., 2020). The quantitative data obtained form the literature review give a first indication of differences between the research and practice field. The qualitative analysis of the indicators from literature and the data form interview gives explanations for the quantitative differences and r-p gaps are identified.

There are multiple reasons given in research for combining quantitative and qualitative methods. For this research, *completeness*, *explanation*, *diversity of views* and *enhancement* are the main reasons for this choice of method (Bryman, 2006). Completeness means that with both qualitative and quantitative data, the subject area of this study is more comprehensively covered. Explanation and enhancement because the data from the interview will help explain and build upon the results from the document analysis. And diversity of views means that the diverse views from researchers and practice and the relationship between them can be better uncovered when both methods are included.

Structured literature review

The first element of the mixed method is a structured literature review. This is done to extract relevant CE indicators for the plastic industry from literature and from practice documents. The quantitative element are the frequency tables that are made based on the included documents. This gives an overview of the differences between the research and practice field in order to identify r-p gaps.

Systemic literature review is the most established way of identifying research-practice gaps (Böckel et al., 2012). Multiple research-practice gap studies used this methodology (Böckel et al., 2021; Tkachenko et al., 2017; Jansen, 2018; Petit-Boix and Leipold, 2018). Systematic literature review is said to be relevant for research with practical relevance (Transfield et al., 2003) and can identify content from academic and practice documents (Böckel et al., 2021). It can be used to collect and analyse data from relevant research (Snyder, 2019). Bias is minimalized by using systematic methods when selecting and reviewing the articles (Snyder, 2019). For the beforementioned reasons, systemic literature review was found to be the most suited method for analysing the documents with CE indicators.

The literature review is designed in a comparative form, since it tries to identify differences between the research and practice field. Comparative design *'entails studying two contrasting cases using more or less identical methods.'* (Bryman, 2012, p 72). The two cases are (1) circularity indicators in research and (2) circularity indicators in practice. They are evaluated with the same method, using the same categories.

These categories are put in frequency tables. This is a quantitative approach to qualitative research (Bryman, 2012), since literature review can also be a qualitative method (Snyder, 2012). The frequency tables are made for the three elements of the analysis: implementation level, discourse and indicator typology. For the implementation level, the amount of documents are counted for both fields and compared. This provides information about the focus level of the research and practice field. For the discourses, the frequency of each discourse is counted for the two fields and compared. This give information about the views about CE in the research and practice field. And for the indicator typologies, the amount of indicators in each typology is counted for the two fields and compared. This will give more in depth information about the two fields and for what phase of the circle the most indicators are developed.

Subsequently, the indicators in each typology are analysed qualitatively. In addition to the quantified number of the amount of indicator in each typology, differences between the research and practice field within each typology are discussed. The indicators form research and practice are analysed on general themes. This will give a more in depth understanding of differences in indicators between the fields and gives an indication of research-practice gaps.

Expert interviews

After the structured literature review, experts are interviewed. The interviews help understand the results from the literature review and get a deeper understanding of the differences.

Expert interviews have multiple advantages. Data from experts can provide contexts that often are not available in the public domain (Von Soest, 2022). General findings can be placed in context with this information. Experts were chosen as interviewees because they are 'well-suited to reducing real-world complexity and bundling together multifaceted phenomena' (Von Soest, 2022, p.2-3), and thus can provide information about a complex concept like CE and the interaction between research and practice. The knowledge of experts can be used as 'affirmation' of prior results (Von Soest, 2022). With the data from expert interviews, the differences found in the literature review can be affirmed of disproved and research-practice gaps are identified.

Experts are people who have specialised knowledge about a topic, or someone who has been involved in a process of subject (Dexter, 2006). In this research, experts are people who have experience with developing or selecting CE indicators, either for research or practice. The authors or developers of the documents included in the literature review are contacted and invited to participate in the interviews. An even distribution between experts in practice indicators and research indicators is aimed for. In addition, an overarching organisation with knowledge on CE monitoring was invited. Further details are discussed in the data collection section.

The most appropriate interview style for this purpose was found to be semi-structured interviewing. The advantages of semi-structured interviews fit the aim of the interviews to identify research-practice gaps: it provides appropriate answers and accurate data as a result of rephrasing and checks of the interviewer; it is an opportunity to uncover unique information that might not be collected using other methods; it is a cost-effective way as not many materials are needed (Alshenqeeti, 2014). However, there are some disadvantages to be aware of. The researcher can bring a subconscious bias in the shape of the question and the scale of the data is often of small size (Alshenqeeti, 2014). Since interviews '*can go hand in hand with other methods*' (Alshenqeeti, 2014, p.43), the qualitative interview data is used to supplement the literature review data. Small sample sizes can suffice this purpose. The bias in the formation of the question is hard to overcome and is present in each form of interviewing. The interviewee must try to formulate the questions as subjective and open as possible, but in semi-structured interviews it is also important to make the interviewee feel at ease and create a flow of conversation (Alshenqeeti, 2014).

This form of interviewing requires an interview guide (see Appendix A. Interview guide) that is roughly followed, leaving room for flexibility to anticipate and react to the given answers (Bryman, 2012). The formulation of the questions can be adapted to the interviewee, since it is important that the interviewer creates an appropriate atmosphere in which the interviewee feels free to speak openly (Alshenqeeti, 2014). It is believed that the topics the interviewee brings up, are found to be relevant for the interviewee. Semi-structured interviews gives the space to explore these topics. In the end of the interview, more or less all the topics and questions of the interview guide should be covered (Bryman, 2012).

4.1.2 Research philosophy

In social sciences, it is important to recognise that the researcher's vision of reality and how it should be studied is closely linked with their method design (Bryman, 2012). This is often expressed in epistemological and ontological terms.

Critical realism is at the epistemological root of the current research. Part of this research is identifying the discourse in which indicators are created. This is typical for critical realism, as *'we will only be able to understand – and so change – the social world if we identify the structures at work that generate those events and discourses.'* (Bhaskar, 1989, p2). For a critical realist, it is acceptable that general mechanisms cannot be observed directly, only their effects (Bryman, 2012). The author recognises it cannot observe the research-practice gaps itself, only elements and effect of the phenomenon. By observing these effects, the general mechanism can be identified. *'What makes critical realism* critical *is that the identification of generative mechanisms offers the prospect of introducing changes that can transform the status quo.'* (Bryman, 2012, p29). By identifying research-practise gaps, the author hopes to transform the status quo so that the gaps are minimised in the future and circularity of the plastic industry is improved.

At the ontological root of this research lies in constructionism. The author's view of society is that it is in a constant state of revision. This is opposed to objectivism, which views social phenomena as an object and is independent from its actors (Bryman, 2012). Social phenomena and organisations are constructed and subjected to constant change. As this research tries to identify gaps in circularity measuring, its underlying goal is to contribute to the optimisation of circularity indicators and thus change the CE measurement construct to eventually change the construct of circular economy in the plastic industry.

4.2 Operationalization and data collection

This section will firstly explain how different elements of the documents are operationalized, followed by how the documents are selected. Secondly, it is explained how the interview questions are build up and supplement the literature review, followed by how the interview data is collected.

4.2.1 Documents

Operationalization

The elements of the documents that are analysed are the implementation level, the discourse and the indicator typology. The operationalization of these three elements is discussed respectively.

Firstly, the implementation level is determined by searching in the article or instrument for the purpose or target audience of the measurement. Small differentiations in literature exist on how these levels are defined. Kirchherr er al. (2017) define micro as products, companies and consumers; meso as eco-industrial parks; and macro as city region, nation and beyond. Elia et al. (2017) use similar differentiation: micro being companies or products; meso being industrial parks; and macro begin cities, regions, nations. Calisto Friant et al. (2020) used for macro-scale planet earth; meso-scale country, region, industrial park, city; and form micro scale single product, service or firm. Corona et al. (2019) only use two categories: 1) products, services, organizations; 2) sectors, regions, global economy. Based on these different divisions of the scales, the implementation levels in this research are differentiated as shown in Table 2.

Table 2. Operationalization implementation level

Implementation level	Target
Macro	Country, large area, industry on (inter)national level
Meso	Industrial plant, industry on local level (incl. waste treatment)
Micro	Product, service, company

Secondly, the operationalize of the discourses is based on the differentiation from the two by two table from Calisto Friant et al. (2020). On the horizontal axis, a differentiation between holistic and segmented is made. On the vertical axis, a differentiation is made between a sceptical and optimistic attitude towards technological innovation.

The article in which the discourses are described (Calisto Friant et al., 2020) is thoroughly searched on the differences between each axes and each discourse, the full table can be found in Appendix B. The main differentiating elements for the holistic-segmented divide were: level of complexity (simpler interpretation, then segmented), inclusion of social elements (not included, then segmented) and R-strategy (lower R-strategies, then segmented). The main differentiating factors between the optimist-sceptical divide were: focus on technological innovation (if yes, then optimist) and innovation and degrowth can go together/eco-economic decoupling (it yes, then optimist). Table 3 shows an overview. The discourse with the most similarities is assigned to the documents.

Table 3. Operationalization of discourses

	Segmented Techno-optimist	Segmented Techno-sceptical	Holistic Techno-optimist	Holistic Techno-sceptical
Level of complextity	simple	simple	complex	complex
Social elements included	no	no	yes	yes
R-strategies	lower ones (R9, R8)	lower ones (R9, R8)	higher ones	higher ones
Technological innovation	yes	no	yes	no
Innovation and degrowth	yes	no	yes	no
	↓ **Technocentric Circular Economy**	↓ **Fortress Circular Economy**	↓ **Reformist Circular Society**	↓ **Transformational Circular Society**

The third element that needs operationalization is the measurement typology. The indicators form the documents are placed in a category to get a better overview of what is measured, so that actual differences can be observed. A categorisation is used adapted from Böckin et al. (2020). This includes the Indicators in Extraction and Production (E&P), Use Phase Indicators, Post Use Indicators and Societal Indicators. Böckin et al. (2020) give example indicators for each typology, which are supplemented with other possible indicators based on important elements of CE mentioned in Calisto Friant et al. (2020) and build up knowledge. These function as reference indicators, guiding the categorisation process and are shown in Table 4.

Subsequently, the data is quantified by calculating the average amount of indicators in each typology for both research and practice. Additionally, qualitative explanations are found in the indicator dataset, supplemented with data from the interviews. This is explained in more detail in the Analysis in 0.

Table 4. Reference indicators per indicator typology

Indicators in Extraction & Production	Use Phase Indicators	Post use Indicaotrs	Societal Indicators
reduce losses in production	use effectively	recycle material	stimulate participation initiatives
reduce material quantity in product without material substitution	reduce use of auxiliary materials and energy	digest anaerobically or compost	implement new business measures
change material in product	share	recover energy	use fairly obtained or produced materials
eco-design	use more of technical lifetime (incl reuse)	treat waste water	equality
	increase technical lifetime by design	landfill and control	knowledge creation
	shift to multiple use	quality of waste stream	circular profits
	maintain		
	repair		
	remanufacture		
	repurpose		

Data collection

The collection of circularity indicators from literature is done with a qualitative systematic review (Snyder, 2019). This entails collecting articles with a strict systematic review process and then assessing the articles with a qualitative approach (Grant & Booth, 2009).

The search queries in Table 5 are used to generate the research data set. The search query does not include a specification for the Netherlands or EU. This is because of the international nature of academic knowledge in combination with the limited research on CE monitoring specified on the Netherlands. It does include a specification for the plastic industry. The databases of Scopus and Web of Science are used for this review. These databases were selected because they include articles from multiple publishers and contain large databases.

Table 5. Search query information

Search engine	Search query	# results
Scopus	(("circular economy") OR (circularity) AND (indicator*) OR (metric) AND (monitor*) OR (measur*) AND (plastic))	37
Web of Science	((“circular economy” OR circularity) AND (indicator* OR metric) AND (monitor* OR measur*) AND (plastic))	28

With 19 overlapping results, the first selection contains 46 articles. The second step in the selection is to evaluate the articles based on the abstract. The inclusion criteria are that (a) the article proposes indicators for monitoring circularity and (b) that the monitoring framework can be used in the plastic industry. The final selection includes 16 articles for this study (see Table 6).

Table 6. Included circularity indicator articles (table continues on next page)

Author	Title	Year
Brouwer M.T., van Velzen E.U.T., Ragaert K., Klooster R.T.,	Technical limits in circularity for plastic packages	2020
Haupt M., Vadenbo C., Hellweg S.,	Do We Have the Right Performance Indicators for the Circular Economy?: Insight into the Swiss Waste Management System	2017
Havas V., Falk-Andersson J., Deshpande P.,	Small circles: The role of physical distance in plastics recycling	2022
Hidalgo-Crespo J., Soto M., Amaya-Rivas J.L., Santos-Méndez M.,	Carbon and water footprint for the recycling process of expanded polystyrene (EPS) post-consumer waste.	2022
Huysman S., De Schaepmeester J., Ragaert K., Dewulf J., De Meester S.,	Performance indicators for a circular economy: A case study on post-industrial plastic waste	2017
Huysveld S., Hubo S., Ragaert K., Dewulf J.,	Advancing circular economy benefit indicators and application on open-loop recycling of mixed and contaminated plastic waste fractions	2019
Milios L., Davani A.E., Yu Y.,	Sustainability impact assessment of increased plastic recycling and future pathways of plastic waste management in Sweden	2018
Moraga G., Huysveld S., De Meester S., Dewulf J.,	Resource efficiency indicators to assess circular economy strategies: A case study on four materials in laptops	2022
Robaina M., Murillo K., Rocha E., Villar J.,	Circular economy in plastic waste - Efficiency analysis of European countries	2020
Roithner C., Rechberger H.,	Implementing the dimension of quality into the conventional quantitative definition of recycling rates	2020

Rossi E., Bertassini A.C., Ferreira C.D.S., Neves do Amaral W.A., Ometto A.R.,	Circular economy indicators for organizations considering sustainability and business models: Plastic, textile and electro-electronic cases	2020
Thakker V., Bakshi B.R.,	Designing Value Chains of Plastic and Paper Carrier Bags for a Sustainable and Circular Economy	2021
Vadoudi K., Deckers P., Demuytere C., Askanian H., Verney V.,	Comparing a material circularity indicator to life cycle assessment: The case of a three-layer plastic packaging	2022
Virtanen M., Manskinen K., Uusitalo V., Syvänne J., Cura K.,	Regional material flow tools to promote circular economy	2019
Zappitelli J., Smith E., Padgett K., Bilec M.M., Babbitt C.W., Khanna V.,	Quantifying Energy and Greenhouse Gas Emissions Embodied in Global Primary Plastic Trade Network	2021
Karman, Agnieszka; Pawlowski, Mieczyslaw	Circular economy competitiveness evaluation model based on the catastrophe progression method	2022

The circularity indicators for businesses are extracted from the collection of 17 instruments compiled by 'Versnellingshuis Nederland Circulair!' (Nederland Circulair!, 2021). Versnellingshuis Nederland Circulair! is an organisation in which the Ministry of Infrastructure and Watermanagement, MKB-Nederland, VNO-NCW, 'Het Groene Brein' and MVO Nederland work together to accelerate the circular economy in the Netherlands. They collected all useful monitoring instruments available for the industry.

The gathered monitoring frameworks are all developed by different organisations. The inclusion criteria for the instruments are (a) they are applicable in the plastic industry in the Netherland and (b) the information about the indicators in the instrument is available. After this final selection, 11 CE instruments were included in the analysis, see Table 7.

Table 7. Included circularity measurement tools

Organisation or company	**Name of instrument**
Ecopreneur	Circularity check
Cradle to Cradle	C2C 4.0
IDEAL&CO	Circularity calculator
Rendemint	PRP ReNtry
Metabolic	Metabolism analysis
Ellen MacArthur Foundation	Circulytics 2.0
WBCSD	Circular Transition Indicators
C-Indicator Advisor	Circular Potential Indicator
+ImpaKT Luxembourg	Product Circularity Data Sheet
Global Sustainable Enterprise System (GSES)	GSES CE Pillar
CIRCit Norden	Circularity Assessment Tool

4.2.2 Interviews

The goal of the interviews is to supplement the data from the literature review with explanations for the differences and to check the validity. Therefore, some concepts need to be operationalized. This section firstly explains how this is done, and secondly explains how the interview data is collected. The full interview guide can be found in Appendix A. This is a guide for semi-structured interviews, which means the formulation and order of questioning may vary between interviews, as was discussed earlier.

Operationalization

The same concepts as in the literature need to be operationalized: the implementation level, discourse and indicator typology. Based on the theoretical framework and the articles form Elia et al. (2017), Calisto Friant et al. (2020) and Bönkin et al. (2020), the following topics are included in the interviews:

- implementation level: On what level should CE be measured? Why?
- discourse: What are differences in the meaning given to CE in research an in practice?
- indicator typology: What are important elements to monitor? What are in your experience differences between indicators from research and from practice?
- explanations: why do these differences exist? What can be done to overcome them?

Data collection

The data from experts was collected by performing interviews with both experts in practice and in research. The question of how many interviews in qualitative research is enough, is often answered with 'it depends' accompanied with 'when knowledge saturation is reached' (Baker and Edwards, n.d.). For this research, the amount of interviews largely depended on the response rate and available time. An even distribution between experts with experience in research and in practice was desirable and aimed for. A total of 16 experts from the research field and a total of 9 experts from the practice field of CE indicators were contacted. A relatively high response rate was present, with respectively 50% and 55% for research and practice experts.

This resulted in the participation of 8 experts. Seven experts were interviewed via a digital meeting platform, of which six were recorded and transcribed. One expert preferred not to be recorded, for which notes were taken during the interview. The eighth expert sent in their answers to the interview questions in written form, which is not a semi-structured interview form. However, the answered were still written from the viewpoint of the expert and valuable answers to include.

The distribution between research and practice expert turned out to be equal: four from the research field and four from the practice field. However, almost all experts indicated to have experience with CE or indicators in both the research and practice field in some way. The experts are anonymised, so that they could speak more freely during the interview. The interviews focussed on the knowledge of the experts and not the organisation they currently worked for. With anonymised interview data, the experts did not have to worry about representing their organisation. In Table 8 the expertise of the experts is described. How the collected data from these experts and from the literature review is analysed, will be discussed in the following section.

Table 8. Expertise of interviewed experts

Expert	Experience
Expert1	Has experience in the research field of plastic packaging industry and circularity. Also familiar with actors in the industry through their research.
Expert2	Has experience in the research field of circular economy, plastic recycling, policies and indicators to assess the effectiveness of policies.
Expert3	Has experience in development of indicator tool to asses sustainability of circular economy in the practice field and experience helping SMEs to select the right indicators. Also has previous experience in research field.
Expert4	Has experience in the research field of circularity indicators and plastics. Also in development of circularity certification for the practice field.
Expert5	Has experience with development of a tool that provides information about the circularity of products, which can be used for any kind of indicator. Also experienced in governmental organisations.
Expert6	Has experience with development of circularity indicators for practice. Has close contact with companies, from large to SMEs.
Expert7	Has experience in the research field in CE indicators. Also developed selection tool with CE indicators for practice.
Expert8	Has experience in the research field of circularity and environmental management solution and tools.

4.3 Analysis

After the data is collected, it is analysed to extract the results. This section explains how the data is analysed. First, the analysis of the literature review is discussed. Second, the analysis of the interview data is explained.

4.3.1 Data from literature review

The data of the literature review consist of two databases with indicators, a research indicator database and a practice indicator database. Each article or instrument is labelled with the corresponding implementation level and the discourse present in the document. Subsequently, the indicators found in the document are placed in one of the indicators typologies.

For all three elements, frequency tables are made (Bryman, 2012). For both the research and practice data set the frequency tables are calculated for:

- The amount of documents aimed at each implementation level
- The amount of documents in each discourse
- The amount of indicators in each typology

Frequencies are calculated by calculated the percentage of the total amount for each element (Bryman, 2012). For the research database, the total amount of documents is 16 and for the practice database, the total amount is 11. The total amount of indicators in calculated after the analysis (see The research articles show a majority of the indicators in the Post Use category (35%), closely followed by 29% in Societal Indicators and 27% in Extraction & Production (E&P). Only a minority of the indicators can be found in the Use Phase typology (9%). In the indicators form practice, we see a majority in E&P (29%) and Societal Indicators (27%). This is followed by Use Phase Indicators (25%) and Post Use (18%). The practice field has less extremes and the indicators are more spread out over the typologies. This is in line with what we concluded in the previous section, where the practice field was found to have a more holistic and broad view of CE.

The E&P and Societal typologies show similar amounts of indicators between the research and practice field. The difference can be seen in the Post Use Indicators and Use Phase Indicators, where respectively a difference of 17% and 16% was found. The practice field has more attention in the Use Phase Indicators, and the research field more in Post Use Indicators. The differences can be a first indication of a research-practice gap, but first we will check the influence of the implementation level.

Table 11 in results). The frequencies of research an practice are compared for a first indication where differences and research-practice gaps occur.

Additionally, the indicators are studied in a qualitative manner. Themes and trends in the dataset are searched by sorting them manually and comparing the indicators from research and practice in each typology.

4.3.2 Data from interviews

The data of the expert interviews consists of 6 transcripts, one documents with written answers to the questions and one document with notes from one interview. This makes a total of 8 documents that were analysed using Atlas.ti software.

Although, there is no fixed way of analysing interview data, a widely used method is with coding (Alshenqeeti, 2014). The transcriptions form the interviews are coded and used to find explanations for the differences found in the literature review. This is the process of '*giving labels (names) to component parts that seem to be of potential theoretical significance and/or that appear to be particularly salient within the social worlds.*' (Bryman, 2012, p568). Open, manual coding process is used (Corbin and Strauss, 1990). It helps the researcher to come to new insights and break out of its standard thinking pattern.

The codes are grouped under the following categories: scale, discourse or meaning of CE, research-practice gaps and measurement typology/indicators. In addition to these groups, some additional codes were created if a recurring theme was suspected. The full coding scheme can be found in Appendix C.

Quotes with similar topics are grouped together by reading through all quotes of a code. The results are integrated with the results from the literature review and some additional findings are subtracted from the interviews.

4.4 Validity and reliability

The objective of validating the research is to reduce the error between the measurement and the true score as much as possible, so that the study measures what it intended to measure (Kimberlin and Winterstein, 2008).

The researcher has the responsibility to design the research as reliable as possible. Reliability of research consists of two element: test-retest reliability and internal consistency (Kimberlin and Winterstein, 2008). The test-retest reliability accounts for the consistency of the test results in time. Internal consistency accounts for the reproducibility of the research, meaning the same results are found by a different researcher using exactly the same methods.

For this research, the author acknowledges that the test-retest reliability is not strong. However, this can be attributed to the nature of the research object. The CE indicators which are develop to this date are used in this research. It is almost certain these CE indicators will change and develop over time, resulting in different outcomes at a later point in time.

The internal consistency is taken into account with a detailed description of the methods. The selection of articles is extensively described and the scoring criteria are clearly explained. For the qualitative part of the research, i.e. the expert interviews, the internal consistence is harder to guarantee, as semi-structured interviews have an element of freedom during the conversation. Here the credibility issue comes at play (Patton, 1999).

The issue of credibility contains three elements: (1) rigorous techniques and methods for gathering high quality data; (2) credibility of the researcher, which is dependant on training, experience, track record, status and presentation of self; and (3) philosophical belief in the value of qualitative research, meaning a fundamental appreciation of qualitative methods (Patton, 1999). The rigorous techniques are explained above with the validity. The credibility of the researcher is being worked on, since a track record of credible peer-review articles is not yet been build as a master student. However, the author has received extensive and recent training on qualitative research. This will be used the best of the author's ability to present credible qualitative results from the interviews.

5 Results

5.1 Implementation level

The implementation level was the first element of the indicators that was studied. This is the scope for which the indicators are made or can be used. Macro is a country, large area or industry on (inter)national level. Meso is an area, industrial plant or industry on local level. Micro is a product, service or company.

In Table 9 we see the amount of research articles in each scope (n-r) next to the amount of instruments for practice in each scope (n-p). Because the total amounts are not equal, in was necessary to calculate the percentages of both fields (subsequently %-r and %-p) in order to draw a fair comparison. The percentages per scope are shown in Graph 1.

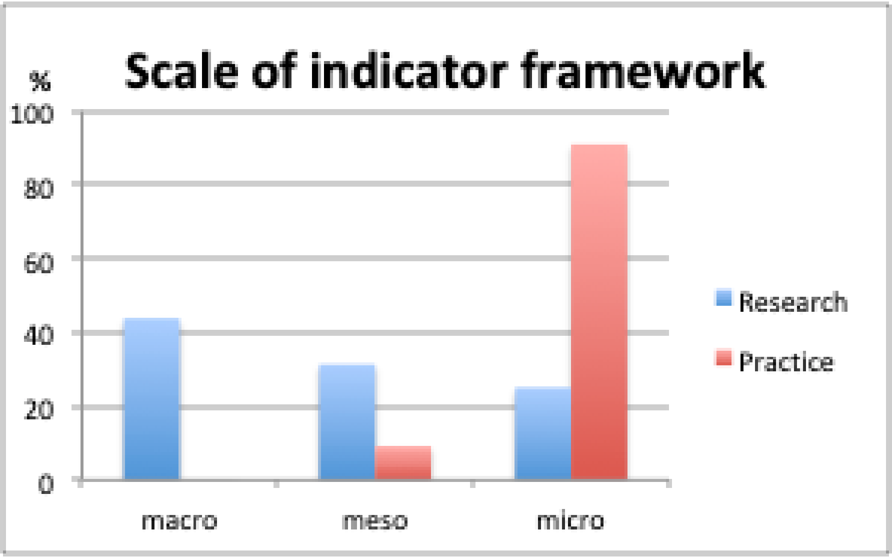
The results of the research field show a small majority at macro level (44%), a bit less at meso level (31%) and the minority in micro level (25%). The practice field sows a significant majority of micro level scope (91%), a small minority at meso level (9%) and nothing at macro scope (see Graph 1). The difference on macro and micro scope between research and practice field are noteworthy.

An explanation for these differences can be found in the document selection and their target audiences. The instruments included in the practice field, are targeted at businesses and thus inherently more focused at micro level implementation. To verify this explanation, we can look at the implementation level of the indicators proposed in policy (PBL, 2021; Eurostat, n.d.; Krebbekx et al., 2022) They all have the implementation level on macro scale, showing that that the nature of the document relates to the implementation level.

It does show an discrepancy between the focus in research articles on circularity indicators in the plastic industry at micro implementation level. The focus in the research field leans more towards macro level, where in the practice field the focus is clearly at micro implementation level. One possible explanations for this was given in the interviews. Multiple interviewees explained that in practice, micro indicators are most important (Expert8), as these can aggregate to higher levels (Expert2). With the data from micro level, the indicators on higher levels will be more accurate (Expert5). Without this data, you cannot have concrete measurements (Expert1).

Table 9. Frequency table of implementation level. With number of research articles (n-r) and tools in practice (n-p), and percentage of articles (%-r) and tools (%-p)

Implementation level	n-r	n-p	%-r	%-p
macro	7	0	44	0
meso	5	1	31	9
micro	4	10	25	91
Total	16	11	100	100



Graph 1. Scale of indicator framework, percentage of documents in both fields.

This difference between research and practice was clearly explained by Expert2, as ‘it is more likely that companies will focus more on micro indicators so they can measure their performance. While […] in research, they look more at a systematic perspective of the circular economy and how a circular economy transition can happen at a broader level in a country, in the European Union, or globally’ (Expert2) In the next section we will go more into the different views on CE between the two field and find an more explanation.

5.2 Discourses

The discourses present in the documents were analysed. Four discourses described by Calisto Friant et al. (2020) were used. They exist in a two by two figure, with on the left side holistic discourses and on the right side segmented discourses. On the top half there are discourses optimistic about technological innovation and on the bottom half they are sceptical about technological innovation (see Figure 1 on p.21). The ‘Reformist Circular Society’ discourse is holistic and techno-optimist; the ‘Transformational Circular Society’ discourse is holistic and techno-sceptical; the Technocentric Circular Economy’ discourse is segmented and techno-optimist; and the ‘Fortress Circular Economy’ discourse is segmented and techno-sceptical.

The frequency table of the indicator datasets is shown in Table 10, where n-r is the number of research articles and n-p the number of instruments in each discourse. Corrected for the unequal total amount of documents in the two field, we see %-r showing the percentage of discourse in the research field and %-p showing the percentage of discourses in the practice field. These percentages are visualised in Graph 2.

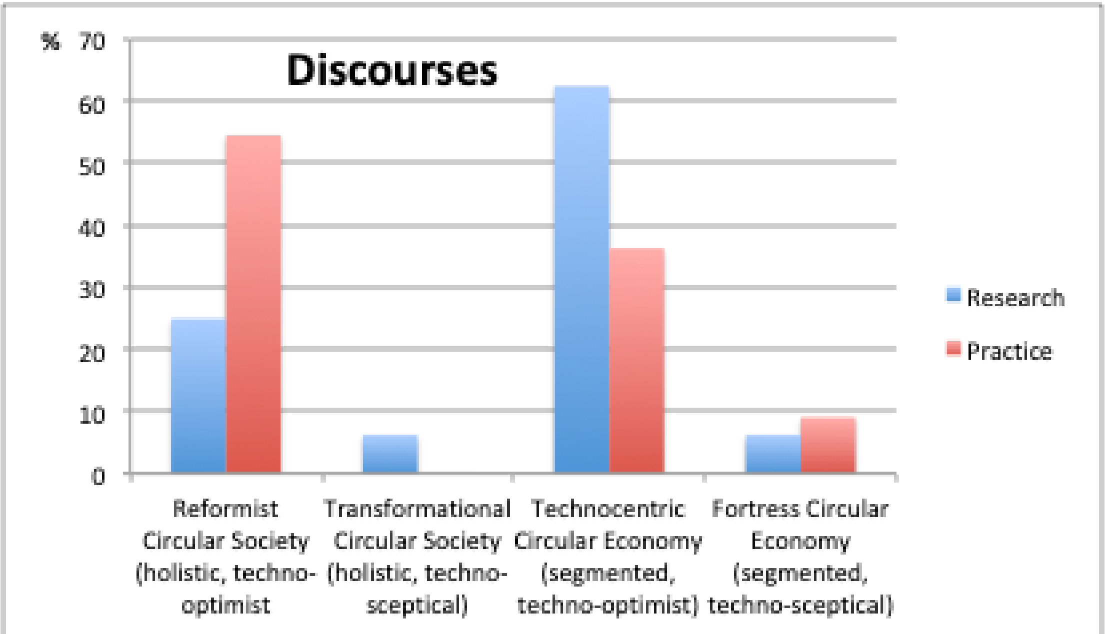
Table 10. Frequency table discourses. With number of research articles (n-r), percentage of research articles (%-r), number of tools in practice (n-p) and percentage of tools in practice (%-p)

Discourses	n-r	n-p	%-r	%-p
Reformist Circular Society (holistic, techno-optimist)	4	6	25	55
Transformational Circular Society (holistic, techno-sceptical)	1	0	6	0
Technocentric Circular Economy (segmented, techno-optimist)	10	4	63	36
Fortress Circular Economy (segmented, techno-sceptical)	1	1	6	9
Total	16	11	100	100

Comparing research and practice, we see a clear difference between the Reformist Circular Society and the Technocentric Circular Economy. Over both fields, a vast majority is in a techno-optimist discourses. Practice has a predominant holistic view and research a predominant segmented view. Research has a clear majority in the Technocentric Circular Economy (63%), more than two fold of the Reformist discourse (25%). For the practice field this is a bit more spread out, but it does have a clear majority (55%) in the Reformist Circular Society discourse followed by the Technocentric Circular Economy (36%).

This means, although both fields hold a techno-optimist view, there is a different view between the two fields on the complexity of CE. The practice field has, for the majority, a broader view and includes more elements in their measurements of a circular economy.

Experts more often observed or assumed the opposite. They mention that research uses more complex definition for CE than practice actors, that practice actors do not really know



Graph 2. Comparison of discourses in percentages

what CE means and that practice looks more to business models and end-of-life, which fits more in the segmented discourse.

Multiple experts observed a difference between research and practice in the ‘achieved level of circularity’, with which they meant the level of development and knowledge that exists. Research is ‘at least five years ahead’ (Expert3) and ‘achieved 50% circularity’ where in industry this is ‘not even 10%’ (Expert4). ‘The amount of knowledge that has been generated [in research] is amazing.’ (Expert3). Both experts have experience in the research and practice field. However, one expert who works closely together with actors in practice, experienced the opposite. They observed that ‘only very abstract and theoretical research about monitoring existed in 2016.’, and took it upon themselves to develop CE indicators together with the industry (Expert6). We see here that the research field seems to contain a lot of knowledge about CE, but it is not transferred or usable in practice.

What also became clear form the interview data, was that there is no consensus on what CE means in both fields (Expert1). Nonetheless, there are differences observed by the interviewed experts. The two fields give meaning of CE on different abstraction levels (Expert1). In the industry, they do not understand ‘fluffy words about regeneration or circular economies based on decoupling value from resource consumption.’. They need more ‘concrete’, ‘operational’, and ‘specific’ definitions (Expert4; Expert2; Expert1). In research the meanings of CE are often more complex. There is a more theoretical approach, in research the question is ‘what should be good to measure?’ (Expert2; Expert8). In practice the question is ‘what can be measured?’.

The different language spoken in the two field is one explanation of why the different views of CE. Expert7 explained that there is no communication stream from research to practice. However, researchers do indicate in the interviews to prefer to include practice in their research, e.g. with case studies, but that in general this is not done enough (Expert8; Expert3; Expert4). It can be concluded that the communication both ways needs to be improved align indicators developed in research better with practice.

One expert, who has experience in both the research and practice field, maybe had the best explanation for the results in Graph 2: ‘Research quite often, even though we try to take a holistic perspective, we still narrow us down to specific topics. We cannot be discussing everything at once. Whereas companies have to deal with everything at once. They have to deal with legal issue, employment, value chains, business marketing. It’s a much more complex environment for them.’ (Expert3)

Concluding what we have seen in this data, indicators from research have a more segmented approach to CE, where indicators in practice are more holistic and include more elements of CE in their measuring. An explanation for this, can be that research articles often are narrowed down to one topic, whereas companies have to focus on all elements at once. In the following section, we will take a deeper look at what the indicators measure in each field and explore differences there.

5.3 Indicator types

The indicator type tells us what elements of the circular economy are measured with the framework. The amount of indicators in the following categories were counted: extraction & production, effective & efficient use, extend use, post use, societal measures.

5.3.1 Amount of available indicators

In The research articles show a majority of the indicators in the Post Use category (35%), closely followed by 29% in Societal Indicators and 27% in Extraction & Production (E&P). Only a minority of the indicators can be found in the Use Phase typology (9%). In the indicators form practice, we see a majority in E&P (29%) and Societal Indicators (27%). This is followed by Use Phase Indicators (25%) and Post Use (18%). The practice field has less extremes and the indicators are more spread out over the typologies. This is in line with what we concluded in the previous section, where the practice field was found to have a more holistic and broad view of CE.

The E&P and Societal typologies show similar amounts of indicators between the research and practice field. The difference can be seen in the Post Use Indicators and Use Phase Indicators, where respectively a difference of 17% and 16% was found. The practice field has more attention in the Use Phase Indicators, and the research field more in Post Use Indicators. The differences can be a first indication of a research-practice gap, but first we will check the influence of the implementation level.

Table 11 the number of indicators from research articles in each category is listen (n-r) next to the number of indicators from practice (n-p). Then, the averages per articles are calculated by dividing the n-r by 16 and the n-p by 11, which is the amount of documents in those fields included in the analysis. Lastly, the percentage for each typology for the two fields are calculated and displayed in Graph 3.

Table 11. Frequency table for indicator typology. With number of research articles (n-r) and tools in practice (n-p), average amount of indicators per document for research (avg-r) and practice (avg-p), and percentage of typology for research (%-r) and practice (%-p)

Indicator typology	n-r	n-p	avg-r	avg-p	%-r	%-p
Indicators in Extraction and Production	25	45	1,6	4,1	27	29
Use Phase Indicators	8	38	0,5	3,5	9	25
Post use Indicators	32	28	2,0	2,5	35	18
Societal Indicators	27	42	1,7	3,8	29	27
Total	92	153	5,8	13,9	100	100

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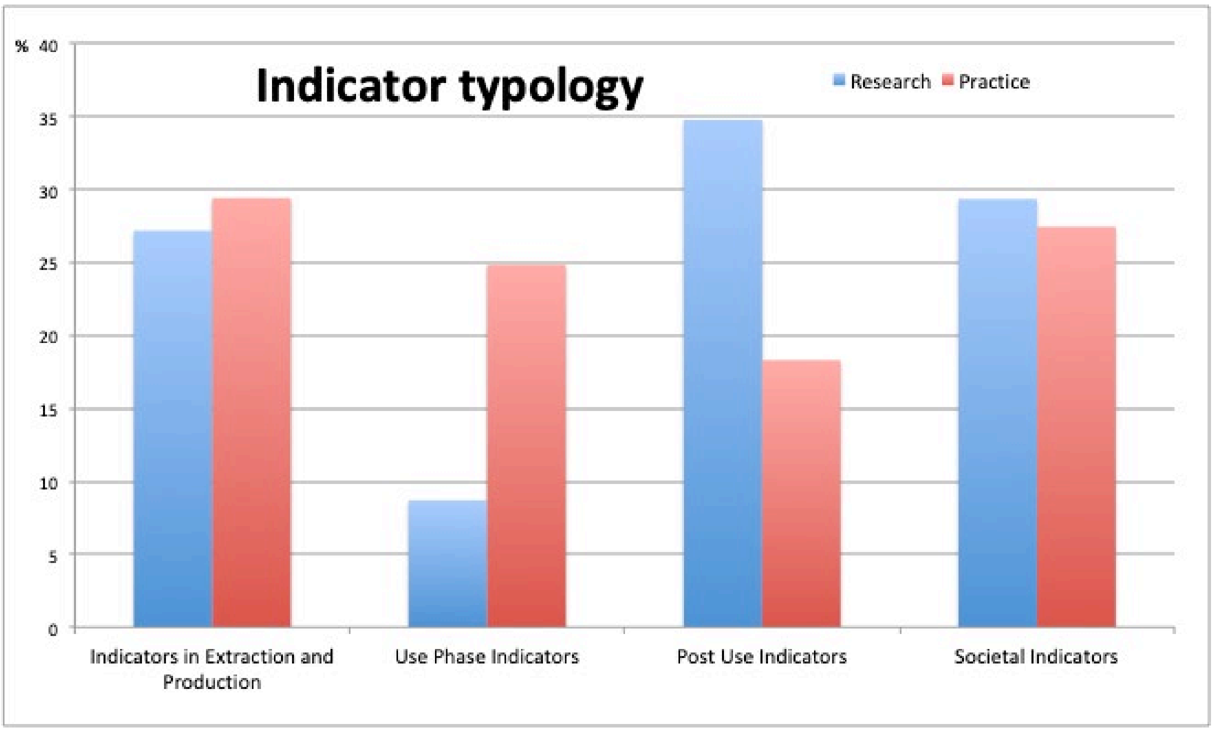
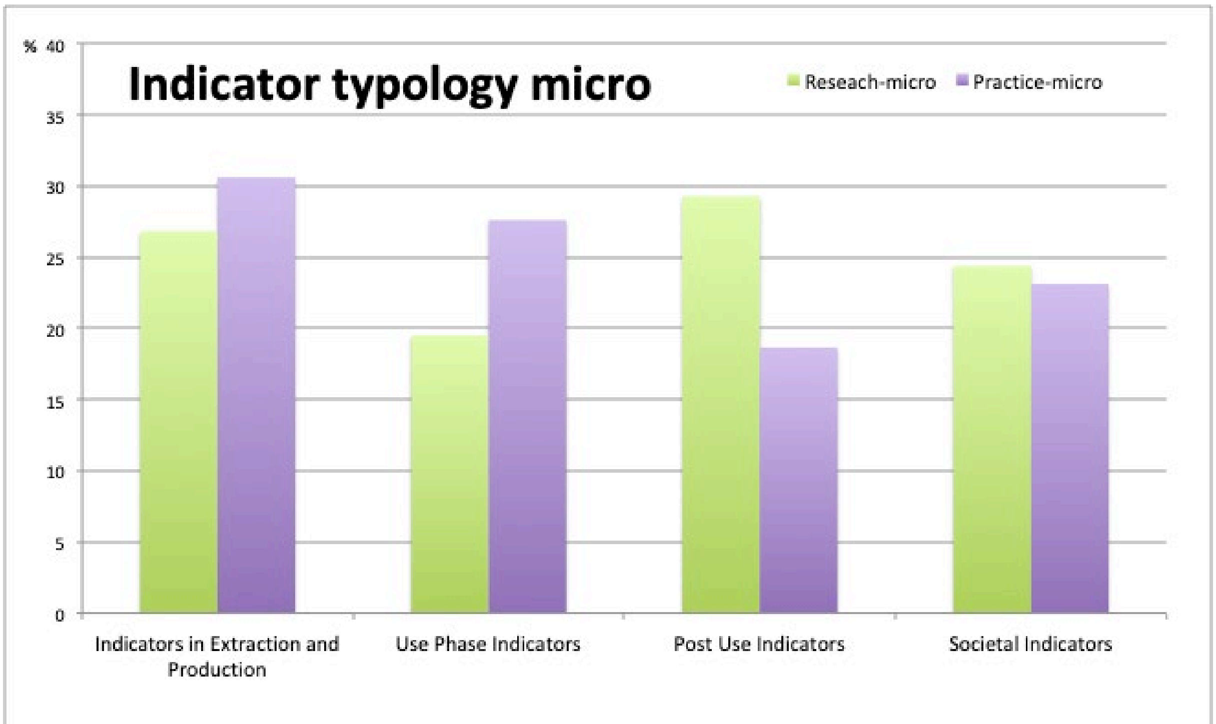


Graph 3. Comparison of indicator typologies in percentages

As we saw in section 5.1, there is a difference in implementation level between research and practice documents. In Graph 4 below we see the percentages of only the documents on micro scale. We have to keep in mind here that the sample sizes changed because of this. The research field only contained 4 documents on micro scale, the practice field contained 10 instruments on micro scale.



Graph 4. Comparison of indicator typologies of micro-level documents (in %)

What we see in Graph 4 is that the differences in amount of Use Phase and Post Use Indicators have decreased a little bit, but are still significantly present in only the micro-level documents. The differences between E&P and Societal Indicators are similar, and thus not much effected by implementation level. This means, even when we exclude the implementation level difference, there is a difference in the amount of indicators available from research and practice in Use Phase and Post Use indicators.

5.3.2 Differences within each typology

A similar amount of available indicators in research and practice, does not mean there are no differences in the indicators within a category.

When we look at the indicators in the Extraction & Production typology, we see two clear differences. First, a noticeable difference is the wording of the indicators. The literature indicator dataset contains indicators like ‘utility of recycled material’ and ‘occupation’, where the in the practice dataset indicators are ‘percentage of cycled content’ and ‘percentage of renewable material’. The indicators in the practice dataset are more often formulated as a statement that can be answered with yes or no, or a level of achievement.

Second, the literature dataset has several ‘footprint’ indicators, which often require a lot of input data and calculations, where the practice dataset does not contain such indicators. The indicators in practice for the E&P typology are easier to calculate and need less data input. Experts observed this difference, saying that practice wants ‘one, two or three simple’ and ‘workable’ indicators (Expert2; Expert7). And that often ‘a full LCA’ or ‘complex formulas’ are used in the research field, which requires a lot of different criteria and input data (Expert2; Expert3).

In the use-phase category we see similar differences. The more straightforward wording and simpler calculation in the practice indicators is also apparent here. The indicators from the practice field are more geared towards practical actions from actors in the plastic industry compared to the few indicators from literature in this typology. Additionally, in both the E&P and use-phase categories it is noticeable that the practice dataset contains more indicators that focus on design, e.g. 'design for maintenance and repair' or 'design in modular construction.'

What seems to be a gap is that the data input needed for some indicators from research, are often not available in practice (Expert2; Expert4). Several reasons are given by the interviewed experts. First, some companies in the plastic industry have more then 400 suppliers and different substances in one product (Expert1), which makes it hard to provide accurate data. Second, companies don't like to share data about economic performances, some data is confidential (Expert4). And third, sometimes a company does not make their internal monitoring public (Expert8).

We haven't yet looked at the differences in the categories Post-Use and Societal indicators. For the Post-Use category, one expert rightly pointed out that on the lower R-hierarchies, towards recycling, the indicators in research and practice become more aligned. Because towards the end-of-life phase, the output streams and different types of waste processing are measured. But activities on higher R-strategies, 'like sharing, pooling, design or reselling are more diverse in what you measure' (Expert3). In the indicators dataset, it indeed seems that in the end-of-life category, the indicators from research and practice are more aligned and measure similar things compared to the other categories.

In the Societal category, the indicators from the research dataset and the practice dataset differ in that practice contains more indicators on social and cultural change and on alternative business models, like 'take back offers', 'percentage of circular strategy and planning' and 'external engagement'. Where in research, there is more focus on financial indicators, e.g. 'circular investment' and 'life-cycle cost'. This was also noted by two experts. In practice, at micro level, it is harder to quantify measures for social elements, and also for financial elements. Most of the indicators have focussed on the environmental part (Expert3; Expert 5).

The lack of economic indicators in practice is surprising. They are said to be equally important as material indicators in practice, since a lot of decisions are based on economic profitability (Expert2). But these indicators are not getting enough attention. A possible explanation for this is that it is not easy to figure out what social indicators are important (Expert2), and companies do not like to share this kind of information (Expert4).

Concluding these results, the wording and calculation are more complex in research, which compromises the usability for actors in practice. The indicators in the practice field are formulated in a more direct way which guides towards action, compared to the more abstract indicators from research. The indicators in the end-of-life phase are more or less aligned in research and practice. In the societal indicator category, research has a larger focus on financial indicators, where practice has a larger focus on new business models and cultural and social change. Table 12 gives and overview of these results. In the next section, some additional findings that were recurring topics in the interviews are discussed.

Table 12 - Summary of indicator differences

	Research dataset	**Practice dataset**
Wording	More complex in E&P en use phase	More formulated in statements
Calculations	More complex formulas, more data input	Less complex, less data needed
Guide toward action	Indirect, abstract value indicators	Direct, more focus on design in E&P and use phase category
End-of-life	More aligned, similar indicators	More aligned, similar indicators
Societal	Focus on financial aspects	Focus on business models, cultural and social change

5.4 Additional findings

Some additional themes were recurring in the expert interviews which are interesting to discuss. Some obstacles and solution for a transition to a circular economy in the plastic industry were given. This includes the role of policy, obstacles for CE monitoring in the plastic industry and standardisation of monitoring.

Indicators from policy were briefly discussed in 5.1 on implementation level. However, the role of policy and politics on circular economy in general and on monitoring is evident and became apparent in the interviews. Governmental organisation are needed when the industry is not implementing a monitoring system themselves, monitoring can be forced with policy (Expert2). However, Expert1 observed that they are not acting now. They explained that politicians often like simple stories and simple solutions, there is no place for nuance. With these simple solutions, they often completely miss the point. Researchers often have more nuance in their work (Expert1), which highlights the importance of the inclusion of research in decision-making. This was also highlighted by expert3: 'Both research and practice contribute to creating a foundation for policymakers to implement some policy.' One expert working for a government viewed the role of the government that it should look at what is needed to enable CE, and then collaborate will all actors, industry and universities included, to build a monitoring system that would work (Expert5).

One expert had a slightly different view, 'research is not needed now' (Expert6). This expert clarified that it is much more important that firstly, the tax system is redesign so that circularity is rewarded instead of fossil and virgin materials. And secondly, there is more aid and support for SMEs to make the transition. Complex, research-based monitoring systems are only usable for big companies with more recourses. The challenge now is help SMEs make the transition. They often have little knowledge, ‘they don’t even know how to build a website, they don’t know what circularity means, what sustainability means or what a lifecycle is.’ (Expert6), the industry doesn’t ‘really understand circularity and they don’t know what is means.’ (Expert4). And Expert3 experienced that companies often are confused when you ask them about circularity. This lack of resources and knowledge in SMEs is the first obstacle for CE monitoring in companies.

A second obstacle of CE monitoring in the plastic industry is trust in the quality of the indicator and trust in the research field. To start with the first trust issue, for CE indicators ‘there is no certainty yet whether they are good enough’ (Expert3). Companies are dependant on what their neighbours are measuring in order to have a good comparison, they are often not sure ‘whether it’s something they could be using in a year.’ (Expert3). Additionally, the reliability of an indicator can be compromised by the developer. This can be the case if it is developed by companies themselves (Expert7). Or this is also observed for indicators developed in research, ‘The industry doesn’t trust what can be found in academic publications.’ (Expert4). Expert1 also had this experience and explained that this is amongst other things because ‘stubborn scientist’ perform LCA calculations with ‘fake numbers’, and saying that recyclers were talking nonsense (Expert1). Even though the recyclers haven’t had much schooling, they knew that some assumptions made were simply not true.

Two solutions mentioned by the expert can solve these trust issues. Firstly, similarly as policy has a role in-between research an practice, consulting companies do too. Expert5 explained that companies often trust these consulting companies more then research articles, they often have well-known logo’s that are associated with reliability and quality (Expert5). Secondly, the standardisation of indicators can help companies, they can be ‘more relaxed’ and know that it will be used by most (Expert3). Currently, there are no guidelines a company needs to comply to. In addition, there are many ways to measure circularity available. An ISO standard for circular economy is under development (Expert7). Although the development process and agreement between involved actors will be a difficult task (Expert7), this will help in the standardisation of CE monitoring.

One two last obstacle that is interesting to discuss for the plastic industry, are the food safety rules and marketing. These two factors determine a of the plastic in the food industry. One expert working with the packaging, observed that EFSA food safety rules often stand in the way of making the packaging industry more circular and was of the opinion there are too many precautionary measures. ‘Nothing is possible’, pleading for more distinction in levels of food safety (Expert1). The second obstacle of marketing causes a lot of unnecessary types colours of plastic and chemicals being introduces to the market. ‘We can survive with a lot less’ (Expert2)

6 Discussion and reflection

6.1 Discussion

The results are critically discussed in combination with the added value this research has to existing literature. Some methodological limitations are also discussed in this section.

Keirstead and Leach (2008) found in their study about Urban Sustainability Indicators that measurability and policy relevance is often prioritised over analytical validity. They analysed this theory practice gap and found that part of the problem are vague definitions of Urban Sustainability. The result of this study correspond with their findings: if the goal of circular economy, or in their case urban sustainability, is not clear, uncertainty about the indicator efforts arise. However, where they argue that more emphasis on the analytical validity is needed to contribute to urban sustainability, the results of this study show that the focus on practical measurability of the indicators should not be compromised. The practicalities of implementing CE indicators are a large factor for the practice field to successfully use the indicators, which is often not accounted for in the research field.

This research built on the study of Böckel et al. (2021) on research-practice gaps in blockchain for a circular economy, by studying research-practice gaps in the related field of CE indicators in the plastic industry. One of their findings was that research has a stronger focus on reduction and reusing strategies. And Kirchherr et al. (2017) state that the ‘reduce’ component of circularity is often neglected by practitioners. This research showed that this r-p gap does not exist for CE indicators in the plastic industry, both field contain indicators for reduction and reusing. However, Böckel et al. (2021) also found the issue of trust that practice actors have with, in their case, entering information about a material passport. This research found similar concerns of practice actors with trust in CE indicators. Their recommendation to do more research on the role of blockchain, can be a solution to increase trust for CE indicators as well. When practice actors trust the indicators they use, they might be more willing to use them correctly which will increase the circularity performance on the plastic industry.

The r-p gap in circular supply chain management that was found by Zhang et al. (2021), was also found for CE indicators in the plastic industry. They found that research mainly addresses economic and environmental performance in CE, where in the practice of CE supply chain management, social sustainability and resilience also play a role (Zhang et al., 2021). This correspond with the r-p gap found in this study. CE indicators from research focus more on financial aspects, where CE indicators in practice focus more on social and cultural elements. In order to optimise CE indicators, indictors for social and cultural elements of CE need to be evaluated in research. And monitoring tools in practice can be optimised to include more financial indicators.

The taxonomy of circular economy indicators that was developed by Saidani et al. (2019) contains a category 'background and origin of the indicator'. This research built on their article by zooming in on this category and identifying research-practice gaps for the plastic industry, with the aim to optimise CE indicators for this industry and increase its circularity. A barrier they identified in their article, is the uptake of indicators by the industry and suggest research on the utilization and utility of circularity indicators on actors in practice. The results from this study, show that various indicators are available for the plastic industry, but often a lack of knowledge and resources in companies, especially SMEs, compromise the use of the indicators. However, the results show that more research is not the most pressing issue (Expert6). In addition to this suggestion of Saidani et al. (2019), it is also important to provide companies with the needed knowledge and resources to implement CE indicators.

One more point of discussion is the environmental impact from circular economy, which is questioned in some articles (Zink and Greyer, 2017; Böckin et al., 2020). The aim of this research is to optimise CE indicators for the plastic industry to increase its circularity, by influencing decision-making and creating accountability for actors in practice. This is with the underlying assumption, based on literature (Stegmann et al., 2022), that a circular plastic industry reduces CO2 emissions, plastic litter and use of crude oil. However, a rebound effect can occur as consequence of a circular economy (Zink and Greyer, 2017) and trade-offs need to be made in the CE transition (Böckin et al., 2020). In the development of CE indicators for the plastic industry, it is therefore important to include or combine indicators that monitor environmental performance.

A methodological limitation, is the subjective element in categorising the indictors. The research design did not include intercoder reliability (ICR), which means it is checked how the data is coded between different coders (O'Connor and Joffe, 2020). This increases the reliability of the research data. Similarly, *intra*coder reliability (consistency in coding within one coder) was not checked. This might have compromised the categorisation of the indicators or the coding of the interviews. On the other hand, elements that do increase the reliability of coding were implemented. The coder had in-depth knowledge on the topic and the boundaries for each category were clear (Bryman, 2012). Although this may have increased the reliability of the data, with the time and resources available, the current level of reliability was the highest possible.

6.2 Reflection

In this section, the author reflects on the research process. A master thesis is often the largest solo project of a student thus far. The master student is still a fairly inexperienced researcher, despite its best efforts. The obstacles experienced by the author and improvements on how this can improve in future research projects are discussed.

Firstly, some aspects might have deserved more background research in the first literature review. There is a lot of research available about circular economy which sometimes was found to be overwhelming. Evaluating the literature research, the author would have liked to go more into depth about the actual effects of monitoring and find more empirical evidence of the positive and negative effects it can have. Now it was assumed that progress needs to be monitored from a governmental perspective in order to guide policy decisions. The author realises there might be more side effects of monitoring progress because it is desirable for policy makers.

Secondly, the author found some processes in the social research set-up to be rather subjective. What elements you focus on, which parts of the interview you use, how you categorise your data. Of course, the author did the best attempt to be as objective and consistent as possible. Especially with designing the methods, the author found that choosing the most appropriate one out of the wide variety of available methods, resulted in a choice for methods with which the author was already familiar with. Nonetheless, the author believed that the current methods was an appropriate choice for answering the research question.

Thirdly, a characteristic of the author is that motivation is often found by seeing the added value for actors and the relevance in society of her work. This research was not performed in cooperation with a research department, PhD student or an internship organisation. For the author, this would have made it easier to see who will benefit from this research and know the added value. However, the author carefully design the research so that it does have scientific and societal relevance. She also realises the added value this research project had on her own development and building of knowledge about the circular economy and monitoring practices.

7 Conclusion and recommendation

As the government of the Netherlands aims for a complete circular economy in 2050, monitoring systems need to be in place to evaluate the current level of circularity. The concept of circular economy is still debated and different interpretations exists. Multiple initiatives for how and what to monitor have been developed the last few years. This research identified gaps between circularity indicators form research and practice in the plastic industry in order to optimise the CE indicators for the plastic industry and increase its circularity performance.

This research answered the research question: '*What are research-practice gaps in circularity measurement in the plastic industry in the Netherlands?*'. It did so by adopting a research strategy which included structured literature review and semi-structured expert interviews. The data was analysed with a special focus on implementation level, CE discourse and indicator typology.

From this data it is concluded that there are research-practice gaps in the understanding and trust between the two field, in their interpretation of CE, and some differences in what the indicators measure. In Table 13 an overview is given of the opportunities for research and the opportunities for practice.

Understanding and trust

Between research and practice there is a lack of understanding and trust in measuring circularity in the plastic industry. It became clear that in research, practice in insufficiently understood. Firstly, research focuses more on macro level than in micro level, while the experts indicate that micro level indicators are the most important level to implement indicators. Indicators on micro level accumulate to higher levels, without micro level indicator you cannot have accurate monitoring on higher levels. Secondly, research uses too complex wording for most actors in practice to understand. Additionally, indicators often contain too complex calculations to be usable in practice. Actors in practice, especially SMEs, have limited knowledge and resources what research do not seem to account for. Thirdly, actors in practice often do not trust indicators directly from academic sources because of seemingly 'false' or incorrect assumptions. At the same time, actors in practice do not always make information available or use circularity as greenwashing, which harms the trust from research in practice. The experts indicate that more practice needs to be taken-up in research.

Interpretation of CE

In both field there is a lot variety in the meaning given to CE and many different indicators are available. Nonetheless, a difference in the interpretation of CE in research and practice is

Table 13. Research-practice gaps conclusions

	Addressed in Research	Not addressed in research
Addressed in practice	Obstacles in research and practice - no uniform definition and complex or the term CE - limited communication streams between research and practice	Inspiration for research - include more practice (case studies, interviews, communication) and understand their practical situation - research on indicators for new business models on micro level - research on use-phase indicators on micro level - use comprehensible wording for indicators
Not addressed in practice	Inspiration for practice - make more data available - develop or use more financial indicators	Opportunities for both fields - standardisation of CE indicators (ISO is being developed).

observed. Research takes a more theoretical approach and focuses more on segmented elements, where in practice a more practical approach is adopted and more elements in their indicator frameworks are included. One explanation for this is that research is often narrowed down to one topic, where companies often have to deal with everything at once.

What the indicators measure

Multiple differences have been found in what the indicators from research and practice measure. In research there are more indictors in the post-use phase. In the societal indicator typology, research focuses more on financial indicators, where in practice there are more indicators focussed on new business models and culture change. Furthermore, indicators from practice contain more use-phase indicators and focus more on the design process.

Recommendations

In this research, it is established that research-practice gaps exists for CE monitoring in the plastic industry in the Netherlands. Bridging these gaps will be the next step in to optimise CE indicators for the plastic industry in order to increase the circularity. Recommendation for future research followed by recommendation for praxis are given.

Future research should focus on closing the research-practice gaps. More specific, this entails firstly, to include more practice, especially SMEs, in research. The implication of transitioning towards a CE for SMEs is not well understood. Second, more review articles are needed to concentrate the knowledge on CE indicators and make it more comprehensible. This can also help in the discussion for the standardisation of CE monitoring. Thirdly, research on micro-level indicators for the use-phase of plastic products and indicators to measure circular business models need to be developed or evaluated in an academic setting.

In addition to closing the research practice gaps, research on how environmental effects correlate with CE monitoring is important, in order to prevent rebound effect or more impact on the environment. And next to including more practice in research, it is also noted that fundamental research about the circular economy should exist. Standardized methods for monitoring circularity are expected to be published in the near future, research in the functioning and implementation of these standards is the next step in optimising CE indicators and increasing CE performance.

For praxis, the recommendation are twofold. Firstly for policy makers, the recommendation is to streamline the development of standardised CE indicators and to support companies with the implementation. To monitor the goal of the government of the Netherland to have a complete circular economy by 2050, it is important that a well functioning monitoring system is in place. Secondly, for the development of indicators in practice, it is important to include environmental performance, financial indicators, and to be transparent. With this transparency, actors can trust the quality of the indicators and it stimulates to improve circularity performance.

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Appendices

A. Interview guide

Theme 1: The extend to which experts experience research-practice gaps

Theme 2: Why gaps might occur

Theme 3: How to overcome the gaps

Intro: My thesis topic is about indicators to measure circularity in the plastic industry. I am comparing indicators developed in research, to indicators developed by organisations to use for businesses. I looked at 3 things: (1) the level of the indicators; micro, meso, macro, (2) the category of the indicators; production, effective use, extend use, post use, societal. (3) CE discourses.

I read your article, about …. / I looked at your tool, made for…

What is your background/expertise? How does it relate to CE indicators? [general]

On what level should circularity be measured? Micro, meso, macro? What level is most beneficial to measure circularity? [verifying results]

What do you think are important elements to measure in order to measure circularity? Why? [verifying results]

In what way do the meanings given to 'circular economy' differ between research and practice? Why do you think this is? [verifying results]

Where are in your experience, gaps between research and practice in CE measurement? [theme 1]

What do you think are differences in indicators developed in research and in practice? [theme 1]

How important is the connection between research and practice in circularity measurement? [theme 2]

How do research and practice supplement each other in creating CE measuring for the plastic industry?

For researcher: To what extend do you think researchers in this field try to make the indicators they used or developed fit to be used in practice? [theme 2]

For practice: To what extend do organisations in this field/did you use research in the development of indicators? [theme 2]

Is the reality of measuring CE in the plastic industry sufficiently taken up in research?

What things can be done to overcome these gaps? [theme 3]

B. Identification of discourses

All differences between discourses mentioned in article Calisto Friant et al. (2020).

	segmented, techno-sceptical	holistic, techno-sceptical	segmented, techno-optimist	holistic, techno-optimist
	Fortress Circular Economy	**Transformational Circular Society**	**Technocentric Circular Economy**	**Reformist Circular Society**
implementation of technological innovation	no	no	yes	yes
innovation can lead to degrowth and eco-economic decoupling	no	no	yes	yes
optimisation of technology	no	no	yes	yes
addresses planetary limits/resource nexus	yes?	yes	no	yes
addresses equality	no	yes	no	yes!
change in social power relation / socio-cultural change	no	yes	no	yes
participation		yes		yes
new business models	yes	no	yes	yes
capitalism and sustainability can coexist	yes (there is no alternative to capitalism)	no	yes	yes
population growth is monitored / restricted	yes	no	no	no
complexity level 1-3	yes		yes	
complexity level 3-5		yes (5)		yes (4)
top down change	yes			
bottom up governance		yes		
life in harmony with the earth / local production		yes		
achieving sustainable development goals				yes
tripilar (economic, social, environmental sustainability)				yes
Refuse	yes	yes		
Reduce	yes	yes		
Reuse/Resell	yes	yes		yes
repair	yes	yes		yes
Refurbish	yes	yes	yes	yes
Remanufacture	yes	yes	yes	yes
Re-purpose	yes	yes	yes	yes
Recycle	yes		yes	yes
Recover energy	yes		yes	
Remine	yes		yes	

C. Coding scheme

- scale: macro
- scale: meso
- scale: micro
- discourse or CE meaning
- measurement typology/indicators
- complexity of CE
- disfunctioning of CE and obstacles
- CE vs sustainability
- business models and economic
- problems: geolocation
- problems: no data available
- energy
- research-practice gap
- practice side
- research side
- r-p connection
- research-practice solution
- political influence and policies

D. The research question answered by chatGPT

This research was written in a time where the use of chatGPTs in education got a lot of attention in society and was discussed in the media. The author likes to clarify that in this theses no parts were written with the help of such a chatbot.

That being said, the author's curiosity leaded her to enter the research question into a chatGPT, for entertainment purposes. The similarity between the results of this theses and the answer of chatGPT amazed the author, especially 1,3 and 5. Here it is one possible answer it generated:

"What are research-practice gaps in circularity measurement in the plastic industry in the Netherlands?"

"There are several research-practice gaps in circularity measurement in the plastic industry in the Netherlands, including:

1. Lack of standardization: There is no standardized method for measuring circularity in the plastic industry, which makes it difficult to compare results across different companies and sectors.
2. Limited focus on downstream activities: Most circularity measurement tools focus on upstream activities, such as recycling and waste reduction, and do not account for downstream activities, such as the use of recycled plastic in new products.
3. Limited consideration of environmental impact: Many circularity indicators focus on the quantity of recycled plastic used, but do not account for the environmental impact of the recycling process or the quality of the recycled plastic.
4. Limited consideration of social impact: Circular economy initiatives can have both positive and negative social impacts, but these are often not taken into account in circularity measurement.
5. Limited integration with business strategy: Circularity measurement tools are often disconnected from business strategy, which makes it difficult for companies to prioritize circularity initiatives and make informed decisions.

Addressing these research-practice gaps will require closer collaboration between researchers and industry stakeholders to develop more robust circularity measurement tools that integrate environmental and social impact considerations and align with business strategy. It will also require the development of standardized methodologies for circularity measurement that can be applied across different companies and sectors."